# Catalogue Data in Autumn Semester 2021

## Agricultural Sciences Bachelor

### 1. Semester

#### First Year Examinations

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

**Abstract**

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

**Objective**

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

**Content**

1. Stoichiometry
   - Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
4. Basics of chemical thermodynamics
   - System and surroundings. Description of state and change of state of chemical systems.
5. First law of thermodynamics
6. Second law of thermodynamics
   - Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
8. Chemical equilibrium
9. Acids and bases
10. Dissolution and precipitation.
    - Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.

**Lecture notes**

Online-Skript mit durchgerechneten Beispielen.

**Literature**


Weiterführende Literatur:


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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-0251-00L</td>
<td>Mathematics I</td>
<td>O</td>
<td>6 credits</td>
<td>4V+2U</td>
<td>F. Da Lio</td>
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**Abstract**

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

**Objective**

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

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.
1. Single-Variable Calculus:
   review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

2. Linear Algebra and Complex Numbers:
   systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.

3. Ordinary Differential Equations:
   separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

4. Genetics and Evolution:
   Mendelian genetics, linkage and chromosomes, evolution of genomes, how evolution works, phylegetic reconstructions, microevolution, species and speciation, macroevolution.

5. Diversity of Life:
   introduction to viruses, prokaryotes, origin and evolution of eukaryotes, nonvascular and seedless vascular plants, seed plants, introduction to fungi, overview of animal diversity, introduction to invertebrates, origin and evolution of vertebrates.

6. Environmental Systems:
   the influence of environmental factors (temperature, radiation, water, nutrients etc.) on organisms; adaptation to certain conditions, biodiversity: variation, causes, threats, conservation, ecosystem compartments, energy and material flows, ecological communities: structure, stability, succession, evolution: method and specialization, conservation strategy.

7. Aquatic Ecology:
   impact of environmental factors (temperature, radiation, water, nutrients etc.) on organisms; adaptation to certain conditions, ecosystem concepts, aquatic and terrestrial ecosystems, corresponding methodological approaches will be presented.

8. Terrestrial Ecology:
   the first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

9. Integrative Ecology:
   the first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

   This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified by using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. A further aim of the lecture is that students achieve an understanding of biodiversity, why it is threatened and how it can be managed.

11. Environmental Systems I
   The lecture provides a science-based exploration of environmental aspects from three research fields: earth, climate, and health sciences. The students are able to explain important properties of the three environmental systems, to discuss critical drivers, trends and conflicts of their use, and to compare potential solutions.
The lecture discusses the role of the environmental systems based on selected environmental problems, among these the exploration of raw materials and fossil fuels, climate change and its impacts on man and environment, and the spread and control of infectious diseases in the human population and agricultural systems.

Slides are provided by instructors and are accessible via moodle.

### 751-0013-00L World Food System

**Abstract**
Knowledge about the World Food System will be provided, based on case studies along food value chains in countries with various development stages and dependent on multiple boundary conditions. This shall generate profound understanding of the associated global challenges especially food scarcity, suboptimal diet and nutrition, food quality and safety as well as effects on the environment.

**Objective**
Attending this course, the students will recognize the elements of the World Food System (WFS) approach and the problems it is supposed to treat. They will especially comprehend the four pillars of global food security, namely (I) food availability (including sustainable production and processing), (II) access to food (physical and monetary), (III) food use (including quality and safety as well as the impact on human health and well being) and (IV) resilience to the boundary conditions (environmental, economic and political). This insight will make them aware of the global driving forces behind our ETH research on food security and is expected to alleviate motivation and understanding for the association of subsequent specific courses within a general context. The course equivalently implements agricultural and food sciences, thus supporting the interdisciplinary view on the WFS scope.

**Content**
Case studies on certain foods of plant and animal origin serve to demonstrate the entire food value chain from the production of raw material to processed food and its consumer relevant property functions. In doing so, important corresponding aspects for developed, emerging and developing countries are demonstrated, by use of engineering as well as natural and social science approaches.

**Lecture notes**
Handouts and links are provided online.

**Literature**
Information on books and other literature references is communicated during the course.

**Prerequisites / notice**
The course is part of the block exam after the first study year. Paper copies can be used ("Open Book") during the on-line exam, but no other means are not allowed. The course is taught in German.

### 351-1158-00L Principles of Economics

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

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

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

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

Market failure: What happens when prices give wrong signals?

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

National accounts: How big is the Swiss economy?

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

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

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

**Lecture notes**
No script available.

**Literature**

Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

**Prerequisites / notice**

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Decision-making</td>
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<td>Problem-solving</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
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<td>Self-direction and Self-management</td>
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### Additional First Year Courses

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0801-00L</td>
<td>Fundamentals of Microscopy and Plant Biology</td>
<td>O</td>
<td>1 credit</td>
<td>1V+2G</td>
<td>E. B. Truernit</td>
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</tbody>
</table>

**Abstract**

**Objective**
Capability of preparing biological specimen, microscopy and documentation. Understanding the correlation between plant structure and function at the level of organs, tissues and cells.

Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.
Content


Anatomical adaptations to different environments.

Lecture notes
Handouts

Literature
For further reading (not obligatory):
Gerhard Wanner: Mikroskopisch-Botanisches Praktikum, Georg Thieme Verlag, Stuttgart.

Prerequisites / notice
Groups of a maximum of 30 students.

529-0030-00L Laboratory Course: Elementary Chemical Techniques O 3 credits 6P A. de Mello, F. Jenny, M. H. Schrotth Abstract
This practical course provides an introduction to elementary laboratory techniques. The experiments cover a wide range of techniques, including analytical and synthetic techniques (e. g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

Objective
This course is intended to provide an overview of experimental chemical methods. The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

Content
The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks:
- Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvatation or precipitation processes) is studied.
- The synthesis of simple inorganic complexes or organic molecules is practised.
- Furthermore, the preparation and handling of environmentally relevant gaseous species like carbon dioxide or nitrogen oxides is a central subject of the Praktikum.

Lecture notes
The script will be published on the web. Details will be provided on the first day of the semester.

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

Prerequisites / notice
Safety conceptt: https://chab.ethz.ch/studium/bachelor1.html

252-0839-00L Informatics O 2 credits 2G L. E. Fässler, M. Dahind L Abstract
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists and tables and with relational databases, introduction to programming.

Objective
The students learn to
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

Content
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to macro programming
5. Introduction to programming with Python

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

Prerequisites / notice
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Basic Courses (Second Year)

Examination Block

Number Title Type ECTS Hours Lecturers
402-0063-00L Physics II O 5 credits 3V+1U A. Vaterlaus

Abstract
Introduction to the concepts and tools in Physics, with the help of demonstration experiments. The Chapters treated are Electromagnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena. Whenever possible, examples relevant to the students’ main field of study are given.

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

Lecture notes
A script will be distributed
### Literature

- **Friedhelm Kuyper**  
  Physik für Ingenieure und Naturwissenschaftler  
  Band 2 Elektrizität, Optik, Wellen  
  Wiley-VCH, 2012  
  ISBN 3527411445, 9783527411443

- **Douglas C. Giancoli**  
  Physik  
  3. erweiterte Auflage  
  Pearson Studium

- **Hans J. Paus**  
  Physik in Experimenten und Beispielen  
  Carl Hanser Verlag, München, 2002, 1068 S.

- **Paul A. Tipler**  
  Physik  
  Spektrum Akademischer Verlag, 1998, 1522 S., ca Fr. 120.-

- **David Halliday Robert Resnick Jeanl Walker**  
  Physik  
  Wiley-VCH, 2003, 1388 S., Fr. 87. (bis 31.12.03)


### 701-0071-00L Mathematics III: Systems Analysis

<table>
<thead>
<tr>
<th>Prerequisites / Literature</th>
<th>Mathematics IV: Statistics</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
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<td>J. Ernest</td>
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- **Abstract**  
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

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

- **Content**  
  [https://iac.ethz.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html](https://iac.ethz.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html)

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

- **Literature**  

### 401-0624-00L Mathematics IV: Statistics

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Mathematics III: Systems Analysis</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
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- **Abstract**  
  Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences. The concepts will be illustrated with some real data examples and applied using the statistical software R.

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

- **Content**  

- **Lecture notes**  
  Ausführliches Skript zur Vorlesung ist erhältlich.

- **Literature**  

### 752-4001-00L Microbiology

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Microbiology</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
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<td>M. Ackermann, M. Schuppler, J. Vorholt-Zambelli</td>
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</table>

- **Abstract**  
  Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

- **Objective**  
  Teaching of basic knowledge in microbiology.

- **Content**  

- **Lecture notes**  
  Wird von den jeweiligen Dozenten ausgegeben.

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

### 701-0501-00L Pedosphere

<table>
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<tr>
<th>Prerequisites / notice</th>
<th>Pedosphere</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
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<td>R. Kretzschmar</td>
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- **Abstract**  
  Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

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

- **Content**  
  Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions, soil fertility, land use and soil degradation.

- **Lecture notes**  
  Polybook  

- **Prerequisites / notice**  
  Prerequisites: Basic knowledge in chemistry, biology and geology.

### 751-1311-00L Introduction to Agricultural Management

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Introduction to Agricultural Management</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
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<td>O</td>
<td>2 credits</td>
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<td>R. Finger</td>
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- **Abstract**  
  Vermittlung von betriebswirtschaftlichen Grundlagenwissen und Analyse- und Planungsinstrumenten mit Anwendung auf Unternehmen der Agrar- und Ernährungswirtschaft.
Objective
Teilnehmer des Kurses sollen am Ende der Vorlesung i) grundlegende Unternehmensentscheide strukturieren und analysieren können, ii) verschiedene Analyse- und Planungs instrumente auf Fragestellungen der Produktionsplanung, Investition und Finanzierung an Beispielen anwenden zu können, iii) verschiedene Werkzeuge zur unternehmerischen Entscheidungsunterstützung anwenden können und iv) die Spezifika von Unternehmen in der Agrar- und Ernährungswirtschaft kennen.

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

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

Lecture notes
Vorlesungsunterlagen werden im Laufe des Semesters zur Verfügung gestellt

Literature

752-6003-00L Introduction to Nutritional Science O 2 credits 1.5V M. B. Zimmermann, C. Wolfrum

Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates.

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

Content
The lectures on micronutrients are given by Prof. Zimmermann and the lectures on macronutrients are given by Prof. Wolfrum. Prof. Zimmermann discusses the micronutrients, including fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. Prof. Wolfrum introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism.

Lecture notes
There is no script. Powerpoint presentations will be made available.

Literature


Agricultural Sciences Basic Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-8003-00L</td>
<td>Genetics in Agricultural Sciences O 2 credits 2G</td>
<td>H. Pausch, B. Studer</td>
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</table>

Abstract
Important concepts from population, quantitative and molecular genetics are introduced and applied to plant and animal populations.

Objective
After the course, the students will be able to
- work with genetic polymorphisms and explain mechanisms underlying allele frequency changes in natural and experimental populations;
- determine factors affecting the selection intensity
- explain the difference between genotypic and phenotypic values
- quantify the expected genetic gain per time unit
- explain important molecular methods to determine genetic polymorphisms;
- map traits in plant and animal populations using molecular marker information;
- integrate different concepts from population, molecular and quantitative genetics and explain their importance for applications in genetics in agricultural sciences.

Content
Molecular genetics (15%)
- DNA sequence variation
- Marker & genotyping technologies (SSRs, AFLPs, SNPs, KASP, GBS, RADseq, AmpSeq, Chip Technologies)

Population genetics (30%)
- Allele- and genotype frequencies in populations
- Hardy-Weinberg equilibrium
- Genetic drift, differentiation of populations
- Fitness, selection
- Inbreeding, relationship, effective population size

Quantitative genetics (40%)
- Recombination, crossing over, linkage analysis, genetic mapping
- QTL mapping
- Forms of selection and selection differential
- Heritability
- Quantification of expected genetic gain
- genotypic value, allele substitution effect, breeding value
- Integrative genetics (15%)
- Genome-wide association mapping
- Estimation of genomic breeding values

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

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

Agricultural Sciences Disciplines

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-1109-00L</td>
<td>Introduction to Microeconomics O 3 credits 2G</td>
<td>M. Wörter, M. Beck</td>
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</table>

Students enrolled in a Master's degree programme may
Der EU Lebensmittelsektor

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

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

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed

Domain C - Social Competencies
- Communication: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed

Microeconomics of the Agriculture and Food Sector

In dieser Vorlesung sollen Mikroökonomische Zusammenhänge am Fallbeispiel des Agrar- und Ernährungssektors vermittelt werden. Ziel ist das Verständnis theoretischer mikroökonomischer Methoden und deren Anwendbarkeit auf den Ernährungssektor.


- Der EU Lebensmittelsektor
- Preiselastizitäten von Angebot und Nachfrage im Ernährungssektor
- Marktformen
- Gewinnmaximierung
- Wettbewerbsangebot
- Monopol/ Monopolistischer Wettbewerb/ Monopson
- Oligopol (Stackelberg, Cournot, Bertrand)
- Preisbildung/ Preisdiskriminierung
- Kartelle
- Dominante Firma

Optimization of Agricultural Production Systems

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

Students will learn the underlying principles (Optimization, Duality, Simplex) and solve exercises in the context of agricultural production. In the second part of the course, the foundation of non-linear programming (NLP) is introduced (Lagrange, Kuhn-Tucker) and illustrated with various examples.

The course is an application of Operations Research (OR). First, the theory and application of linear programming (LP) is presented.

Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Resource and Environmental Economics

Students acquire a deeper understanding of basic microeconomic models.

Concepts and Theories

- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

- Analytics and Flexibility: not assessed

- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.

Note for D-MAVT students: If you have already successfully completed "Principles of Microeconomics" (LE 363-0503-00L), then you will not be permitted to attend it again.
Abstract
Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

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

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

Literature

752-2120-00L Consumer Behaviour I W 2 credits 2V M. Siegrist, A. Beardh, A. Berthold
Abstract
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

Objective
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

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

Literature

751-5005-00L Agroecology and the Transition to Sustainable Food Systems W 2 credits 2G M. Sonneveldt, M. Grant, S. E. Ulbrich, B. Wehrli
Abstract
The aim of this lecture series is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html

Objective
Students know the elements of agroecology and are able to critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches. Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions. This course enables students and the interested public to engage in a lively and critical debate on important topics and scientific contributions to agroecology. Based on the knowledge gained, students are able to form a personal opinion on the role of agroecology and to reflect on the different facets and real-world applications supporting a transition towards sustainable food systems.

Content
Organization of the lecture:
The lecture series will take place in the fall semester of ETH Zurich, starting in the week of September 20, 2021 and lasting until December 17, 2021. During this period, the lecture will take place once a week, on Tuesdays from 18:00-20:00 (CEST/CET). Each lecture will be organized in an online format and will be set up in two parts consisting of a public and a student lecture: At the end of the lecture series, the course will be evaluated with the students.

Public lecture part (virtually via Zoom webinar):
The public lecture (18:00-19:00 CEST/CET) will take place virtually via this Zoom webinar: https://ethz.zoom.us/j/64352765873.

While most public lectures will take one hour, the last public lecture on “Agroecology, The Way Forward”, on Tuesday, 7th December 2021, will last 90 minutes.

Student’s lecture part (exchange with course instructors online via zoom):
The student’s lecture (19:15-20:00h CEST/CET) will take place online via a normal Zoom call: https://ethz.zoom.us/j/61315399346.

For further details, please refer to the Moodle-page of this course: https://moodle-app2.let.ethz.ch/course/view.php?id=15210

On the Moodle-page you can find some pre-readings for the course.


Prerequisites and notice
The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.

Plant Sciences

751-3700-00L Plant Ecophysiology O 2 credits 2V M. Gharun, M. Lehmann, A. Walter
Abstract
The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Lab and field measurements are included.

Objective
The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology and will have hands-on experiences with equipment used in plant ecophysiology.

Lecture notes:
Handouts stehen online.

Literature:

Prerequisites / notice:
Dieser Kurs basiert auf Grundlagen der Pflanzenbestimmung und der Pflanzenphysiologie. Er ist Basis für die Veranstaltungen Pflanzenbau, Teil Futterbau und Graslandsysteme.

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<tr>
<th>Kursnummer</th>
<th>Titel</th>
<th>Modul</th>
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<th>Vorlesung</th>
<th>Tutor</th>
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<tr>
<td>751-3401-00L</td>
<td>Plant Nutrition I</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Frossard</td>
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**Abstract:**
The aim of these lecture is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

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

**Content:**
A general introduction explains the appropriately managing nutrients in plant production. Afterwards, we will study the physiology of plant nutrition (nutrient uptake by roots; nutrient transports in the plant; physiological roles of nutrients in the plant). Then the role of nutrients for yield formation and their effects on crop quality is dealt with. Finally, the bases of crop fertilization are taught (availability of nutrient in soil; N, P and K fertilization; different types of fertilizers).

**Lecture notes:**
The slides will be distributed online.

**Literature:**
Schubert S 2006 Pflanzenernährung Grundwissen Bachelor Ulmer UTB
Richner W. & Sinaj S., 2017. Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD 2017). Agrarforschung Schweiz 8 (6), Spezialpublikation,
http://www.tll.de/visuplant/vp_idx.htm

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<th>Vorlesung</th>
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<tr>
<td>751-4108-00L</td>
<td>Innovation in Smart Farming</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>A. Walter</td>
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**Abstract:**
A motivation letter must be submitted after the first lecture Monday 27.9. (maximum 100 words) until 29.9. to Achim Walter (Achim.Walter@usys.ethz.ch). A confirmation of the definitive participation in the course will be communicated on 1.10. The definitive registration for the course will be undertaken by the study secretariat.

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

**Content:**

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<th>Tutor</th>
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<tr>
<td>751-4504-00L</td>
<td>Plant Pathology I</td>
<td>W+</td>
<td>2</td>
<td>2G</td>
<td>B. McDonald</td>
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**Abstract:**
Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

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

Lecture Topics and Tentative Schedule

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

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

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

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

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

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


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

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

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


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

Week 13  Cultural control methods: fertilizers, crop rotations.

Week 14  Open lecture.

Lecture notes
Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

751-4801-00L System-Oriented Management of Herbivore Insects W+ 2 credits 2G to be announced

Abstract
Does not take place this semester.

Objective
The focus is on the potential to assess strategies and tactics of pest management, in view of the demands from the economy, environment and society. Significant management measures will be explained using practical examples, such as surveillance and forecasting, resistance management, biological control as well as the use of plant protection products, incl. regulatory aspects and ecotoxicology.

751-5003-00L Sustainable Agroecosystems II W+ 2 credits 2V K. Benabderrazik, M. Hartmann

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

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

Content
The course will address a wide range of agricultural and food system challenges (e.g. food security, climate change, soil degradation, etc.) in both temperate and tropical contexts, from building food system resilience through innovative measures, to addressing soil fertility and GHG emissions. A wide variety of case studies will be presented, covering different scales (e.g. value-chains, farm and soil management). The class is complemented by a role-playing exercise on food system transformation. Students will gain an overview on institutions and actors’ roles in the field of sustainable agricultural development. Throughout the exercise, students will learn to cooperate through a teamwork exercise and understand what is the role of each stakeholder in the food system in order to support a sustainable transformation.

Literature

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

The overall goal of this course is to provide general knowledge about the behaviour, housing and welfare of domestic animals. The importance and specificities of the different horticultural crops are shown in this course in the autumn semester. It deals with fruit growing (8 h), berry production (4 h), vegetables (6 h) and viticulture (6 h). Under the responsibility of Agroscope representatives, basic knowledge of production systems (yield formation and physiology, cultivation methods, main varieties, quality) of these horticultural crops, which are important in Switzerland, is imparted.

The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives and different facets and real-world applications supporting a transition towards sustainable food systems. Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions.

Agroecology and the Transition to Sustainable Food Systems

The aim of this lecture series is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html

The lecture series will take place in the fall semester of ETH Zurich, starting in the week of September 20, 2021 and lasting until December 17, 2021. During this period, the lecture will take place once a week, on Tuesdays from 18:00-20:00 (CEST/CET).

At the end of the lecture series, the course will be evaluated with the students. Public lecture part (virtually via Zoom webinar):

The public lecture (18:00-19:00 CEST/CET) will take place virtually via this Zoom webinar: https://ethz.zoom.us/j/64352765873.

While most public lectures will take one hour, the last public lecture on “Agroecology, The Way Forward”, on Tuesday, 7th December 2021, will last 90 minutes.

Student’s lecture part (exchange with course instructors online via zoom):

The student’s lecture (19:15-20:00h CEST/CET) will take place online via a normal Zoom call: https://ethz.zoom.us/j/61315399346.

For further details, please refer to the Moodle-page of this course: https://moodle-app2.let.ethz.ch/course/view.php?id=15210


The lecture notes can be found on the Moodle-page you can find some pre-readings for the course.

Prerequisites

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

The student's lecture (19:15-20:00h CEST/CET) will be set up in two parts consisting of a public and a student lecture:

At the end of the lecture series, the course will be evaluated with the students.

Animal Sciences

Number  Title                                    Type  ECTS  Hours  Lecturers
751-6101-00L  Anatomy and Physiology of Man and Animals I  O  2 credits  2V  S. E. Ulbrich, T. Fleischmann, J. Müller

751-7505-00L  Agroecology and the Transition to Sustainable Food Systems  W  2 credits  2G  M. Sonneveld, M. Grant, S. E. Ulbrich, B. Wehrli

751-7506-00L  Animal Housing and Behaviour  O  1 credit  1V  J. Müller, S. Goumon

The basics of planning of feeding and formulation of diets incl. the implications on nutrient cycles and balances are taught. In the part 2, G. Bee, M. A. Boessinger, - Programmteil Wiederkäuer: Einführung in die Winterfütterungsplanung für Milchkühe, Betriebsbesuch (Erfassung aller notwendigen Daten).

Agroecology and the Transition to Sustainable Food

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

Performance Assessment: 1 written report (20%) + 1 final examination (80% of grade)

Applied Animal Nutrition

The basics of planning of feeding and formulation of diets incl. the implications on nutrient cycles and balances are taught. In the part dealing with ruminants, forage-based diets and the application of feed formulation programs are central and exercised on-farm. With pigs and poultry, the basics of energy and nutrient requirements are deepened through practical examples.

Performance Assessment: 1 written report (20%) + 1 final examination (80% of grade)

Animal Feed and Feeding of Ruminants

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

Performance Assessment: 1 written report (20%) + 1 final examination (80% of grade)

Regulatory Physiology

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

Performance Assessment: 1 written report (20%) + 1 final examination (80% of grade)

Agroecology and the Transition to Sustainable Food Systems

The aim of this lecture series is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html

Performance Assessment: 1 written report (20%) + 1 final examination (80% of grade)
Objective

Students know the elements of agroecology and are able to critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches.

Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions.

This course enables students and an interested public to engage in a lively and critical debate and to learn about scientific contributions to agroecology. Based on the knowledge gained, students are able to form a personal opinion on the role of agroecology and to reflect on the different facets and real-world applications supporting a transition towards sustainable food systems.

Content

Organization of the lecture:

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Lecture notes

On the Moodle-page you can find some pre-readings for the course.

Literature


Prerequisites / notice

The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.

Methods

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0441-00L</td>
<td>Scientific Analysis and Presentation of Data</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>W. Eugster</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Students will get an introduction to the scientific work with data covering all steps from data import from Excel via statistical analyses to producing correct scientific graphical output. Exercises with the software R/RSStudio will provide hands-on opportunities to get acquainted with data analysis and presentation in adequate graphs. Field data gathered with Prof. E. Frossard will be used.</td>
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<td>Tentative Programme:</td>
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<td>- Introduction</td>
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<td>- Introduction to ‘R’</td>
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<td>- Data import and graphical presentation</td>
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<td>- Preparation of own data from field course with Prof. E. Frossard / from 4th semester</td>
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<td>- Correct and problematic graphical data displays</td>
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<td>- Statistical distribution and confidence intervals</td>
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<td>- Statistical tests - Repetition and hands-on applications</td>
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<td>- Analysis of Variance</td>
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<td>- Discussion of ANOVA results with Prof. E. Frossard</td>
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<td></td>
<td>Last week of semester: examination (Leistungskontrolle)</td>
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<td></td>
<td>The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.</td>
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<tr>
<td>Lecture notes</td>
<td>Mainly German (with some English passages from text books)</td>
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<td>Prerequisites / notice</td>
<td>Theoretical background in ensemble statistics from the mandatory course in the 4th semester; students should have cleared the examination of that fundamental course to be able to follow</td>
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<tr>
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<th>Type</th>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Die Studierenden kennen die Grundlagen und die Konventionen des wissenschaftlichen Schreibens in den Naturwissenschaften, können wissenschaftliche Literatur suchen und verwalten sowie wissenschaftliche Publikationen analysieren. Sie setzen das Gelernte beim Schreiben eines eigenen Textes um.</td>
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<td>Objective</td>
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<td>Die Studierenden kennen die Grundlagen und die Konventionen des wissenschaftlichen Schreibens in den Naturwissenschaften. Sie setzen das Gelernte beim Schreiben eines kritischen Literaturberichtes zu einem agrarwissenschaftlichen Thema ihrer Wahl um. Die Lehrveranstaltung bereitet die Studierenden auf weitere schriftliche Arbeiten im Studium der Agrarwissenschaften vor, beispielsweise auf die Bachelor-Arbeit.</td>
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<tr>
<td>Lecture notes</td>
<td>Es wird ein Skript abgegeben.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Die Note für die LV Wissenschaftliches Arbeiten (Teil I: Grundlagen (WIA) und Teil II: Wissenschaftliches Schreiben (WiSch)) setzt sich aus den Leistungen der Lehrveranstaltungen im 4. und 5. Semester zusammen. Die Note für WiSch (5. Sem.) zählt zu 80% zur Gesamtnote.</td>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0206-00L</td>
<td>Applied Laboratory Techniques in Agricultural Sciences The course is compulsory for students in 5th semester BSc Agricultural Sciences.</td>
<td>O</td>
<td>4</td>
<td>4P</td>
<td>G. Broginni, M. Gharun, M. Hartmann, S. Neuenschwander, L. P. Schönholzer, B. Studer, S. Yates</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Die Lehrveranstaltung ist zweiteilig aus einem Laborpraktikum und einem angewandten Methodentraining aufgebaut. Im Laborpraktikum werden an 6 Kurstagen die wichtigsten Techniken der Molekularbiologie gelehrt. Das folgende Methodentraining findet an 5 Kurstagen im Block in einer der beteiligten Forschungsgruppen statt, um die wichtigsten Methoden aus dem jeweiligen Fachgebiet praxisnah anzuwenden.</td>
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In this course, students will learn the principles of linear and non-linear optimization in the context of agricultural production, including the use of the simplex method and the Kuhn-Tucker conditions. Students will also learn how to formulate and solve optimization problems using linear and non-linear programming models. Additionally, students will be introduced to the concept of duality in optimization theory.

### Objective
- An understanding of the economic principles underlying agricultural production systems.
- The ability to formulate and solve optimization problems using linear and non-linear programming models.
- The ability to interpret the results of optimization models and critically discuss their implications.

### Content
Molecular biological laboratory: DNA extraction, DNA quantification, PCR, molecular markers, gel electrophoresis, DNA sequencing, bioinformatics, qPCR.

Angewandtes Methodentraining: Inhalte definiert durch die jeweiligen Arbeitsgruppen.

### Literature

### Taught competencies
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed

### Practical
- Hands on during lecture

### Examinations
- Written examination

### Prerequisites
- Grundkenntnisse der Ökonomie/Agrarökonomie
- Vorlesung Einführung in die Mikroökonomie

### Electives
The electives listed are recommended. However, electives can be chosen from the complete course offer of the ETH Zurich and University of Zurich.

### Course number and credits
- 751-0903-00L 3 credits
- 751-0401-00L 3 credits
- 363-0537-00L 3 credits
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature

### 752-2120-00L Consumer Behaviour I

**Abstract**
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

**Objective**
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior.

### 751-4108-00L Innovation in Smart Farming

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

**Objective**
During the course, the students generate their own ideas on 'Smart Farming'. They explore, which technologies provide possibilities for a more sustainable agriculture. They realize trade-offs between economic and technological possibilities.

**Content**

### 751-4504-00L Plant Pathology I

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

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

Lecture Topics and Tentative Schedule

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

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

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

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

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

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


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

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

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


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

Week 13  Cultural control methods: fertilizers, crop rotations.

Week 14  Open lecture.

Lecture notes

751-4801-00L System-Oriented Management of Herbivore Insects W 2 credits 2G to be announced

Abstract

Does not take place this semester.

The focus is on the potential to assess strategies and tactics of pest management, in view of the demands from the economy, environment and society. Significant management measures will be explained using practical examples, such as surveillance and forecasting, resistance management, biological control as well as the use of plant protection products, incl. regulatory aspects and ecoxotoxicology.

Objective

The students gain a good understanding of fundamental aspects of pest management in agroecosystems. They will be able to assess options for action in view of requirements from the economy, environment and society. Further, they will learn to elaborate on current issues in pest management, and to critically evaluate case studies.

751-5003-00L Sustainable Agroecosystems II W 2 credits 2V

K. Benabderrazik, M. Hartmann

Abstract

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

Objective

1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.

2) Learn and experiment on methods for field and laboratory investigations in agroecology.

3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.

4) Reflect critically on agricultural and food system transformation tools and methods from the perspective a food system stakeholder.

5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

Content

The course will address a wide range of agricultural and food system challenges (e.g. food security, climate change, soil degradation, etc.) in both temperate and tropical contexts, from building food system resilience through innovative measures, to addressing soil fertility and GHG emissions. A wide variety of case studies will be presented, covering different scales (e.g. value-chains, farm and soil management). The class is completed by a role-playing exercise on food system transformation. Students will gain an overview on institutions and actors’ roles in the field of sustainable agricultural development. Throughout the exercise, students will learn to cooperate through a teamwork exercise and understand what is the role of each stakeholder in the food system in order to support a sustainable transformation.

Literature


Prerequisites / notice

Prior participation in the lecture Nachhaltige Agrärösosysteme I (Sustainable Agroecosystems I) 751-5000-00G (spring term) recommended.
The basics of planning of feeding and formulation of diets incl. the implications on nutrient cycles and balances are taught. In the part dealing with ruminants, forage-based diets and the application of feed formulation programs are central and exercised on-farm. With pigs and poultry, the basics of energy and nutrient requirements are deepened through practical examples.

Objective
The students are able, based on the knowledge they obtain in this course, to deal with problems in the nutrition of ruminants, pigs and poultry on farm.

Content
- Programmteil Wiederkäuer: Einführung in die Winterfütterungsplanung für Milchkühe, Betriebsbesuch (Erfassung aller notwendigen Daten inkl. Futterprobenentnahme für eine konkrete Planung auf einem Praxistrieb), Besonderheiten der Milchviehfütterung (Laktationsverlauf, Jahreszeit, etc.); Einführung in den LBL-Fütterungsplan, Möglichkeiten der Futterbeurteilung und -bewertung mit praktischer Beurteilung der gesammelten Proben, Berechnungen und Besprechung Fütterungsplan, Aufstellung der Mineralstoffbilanz, Vorführung von PC-Software zur Fütterungsplanung Vorstellen und diskutieren des Fütterungplanes auf dem Praxistrieb durch die Gruppe.
- Programmteil Nicht-Wiederkäuer: Der Energie- und spezifische Nährstoffbedarf beim Schwein und Geflügel; Besonderheiten der Fütterung in den verschiedenen Produktionsphasen; Fütterungsempfehlungen und -hinweise. Rationengestaltung und Rezeptoptimierung für Mischfutterteilen anhand verschiedener Beispiele; Einsatzgrenzen von Futtermitteln; technologische Futterbearbeitung.

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

Literature
Die Dozierenden geben in der Lehrveranstaltung die relevante Literatur bekannt.

Prerequisites / notice
Blockkurs in Halbtagesform; eingeschlossen sind Betriebsbesuche. Fach mit benoteter Semesterleistung.

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

Objective
Purchase of basic skills in agricultural livestock nutrition.

Content

Prerequisites / notice
Fach mit benoteter Semesterleistung.

---

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

Objective

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

Lecture notes
Unterlagen werden individuell von den Dozierenden abgegeben.

Prerequisites / notice
Spezifische Literatur wird individuell von den Dozierenden angegeben.

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Abstract
The aim of this lecture series is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: [https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html](https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html).

Objective
Students know the elements of agroecology and are able to critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches. Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions. This course enables students and an interested public to engage in a lively and critical debate and to learn about scientific contributions to agroecology. Based on the knowledge gained, students are able to form a personal opinion on the role of agroecology and to reflect on the different facets and real-world applications supporting a transition towards sustainable food systems.
Organization of the lecture:
The lecture series will take place in the fall semester of ETH Zurich, starting in the week of September 20, 2021 and lasting until December 17, 2021. During this period, the lecture will take place once a week, on Tuesdays from 18:00-20:00 (CEST/CET).
Each lecture will be organized in an online format and will be set up in two parts consisting of a public and a student lecture:
At the end of the lecture series, the course will be evaluated with the students.

Public lecture part (virtually via Zoom webinar):
The public lecture (18:00-19:00 CEST/CET) will take place virtually via this Zoom webinar: https://ethz.zoom.us/j/64352765873.
While most public lectures will take one hour, the last public lecture on “Agroecology, The Way Forward”, on Tuesday, 7th December 2021, will last 90 minutes.

Student’s lecture part (exchange with course instructors online via zoom):
The student’s lecture (19:15-20:00h CEST/CET) will take place online via a normal Zoom call: https://ethz.zoom.us/j/6131599346.

For further details, please refer to the Moodle-page of this course: https://moodle-app2.let.ethz.ch/course/view.php?id=15210

Lecture notes
On the Moodle-page you can find some pre-readings for the course.

Literature

Prerequisites / notice
The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.

701-0903-00L The Sustainable Development Goals Book Club W+ 2 credits B. B. Pearce, J. Ghazoul

Abstract
The ETH Sustainable Development Goals Book Club is a colloquium for Bachelor students within and outside of Department of Environmental Systems Science centered around the discussion of themes from a single book, with the aim of fostering interdisciplinary, intellectual and critical exploration of the scientific and societal complexities related to the Sustainable Development Goals.

Objective
The aims of this course are to:
- Create an interdisciplinary approach to understanding key concepts of sustainable development and the SDGs
- Create solidarity through a cultural of intellectual exchange at ETH Zurich
- Create a common object of intellectual reference for students with different disciplinary interests to enable diverse ways and modes of thinking

Content
The course is similar to 701-0019-00L Readings in Environmental Thinking with the following differences:
- Targeted at Bachelor’s students (especially first and second year, but open to all) within and outside of the department.
- All participating students will read one book whose themes will be the basis for discussions.
- These discussions, taking place both online and in-person, will be moderated by the main lecturers of the course and discussed by additional professors from within and outside of D-USYS.
- Each discussion will be based on a chapter of a book, always linked to a particular aspect of the SDGs.
- The modes of discussion will vary in length and form, ranging from the traditional, sit-down meeting, to a Twitter book club format (as already pioneered and popularized by author Robert MacFarlane).
- Both students and professors will lead the discussions alternatively.
- Each discussion session will result in a visual output or another shareable output that will be developed by a student or group of students.

Literature
TBD
Could be one of the books already used in 701-0019-00L Readings in Environmental Thinking (Silent Spring, The Sand County Almanac, Collapse..etc.)
Other possibilities:
- Thinking in systems
- Limits to Growth
- Operating Manual for Spaceship Earth
- Small is Beautiful
- For the Common Good
- Factfulness
- The Prize: The Epic Quest for Oil, Money and Power (history of the global petroleum industry from 1850s-1990)

Prerequisites / notice
none

Bachelor’s Thesis

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<td>751-1020-10L</td>
<td>Bachelor’s Thesis</td>
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<td>14 credits</td>
<td>30D</td>
<td>Lecturers</td>
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Agricultural Sciences Bachelor - Key for Type

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

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Educational Science

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<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
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<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<td>Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissensstrahlers; Lernen durch Instruktion und Erklärungen: Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td>Lecture notes</td>
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<td>Folien werden zur Verfügung gestellt.</td>
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<td>Prerequisites / notice</td>
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<td>This lecture is only apt for students who intend to enrol in the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects ■ W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<td>Objective</td>
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<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<td>- Get information about recent literature on learning and instruction</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td>Number of participants limited to 30.</td>
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<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<td></td>
<td>- Understanding of research methods used in the empirical human sciences</td>
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<td>- Getting to know intelligence tests</td>
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<td>- Understanding findings relevant for education</td>
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<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
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<td>Number of participants limited to 30.</td>
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<td>Abstract</td>
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<td>Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.</td>
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<td>- Understand research methods used in the empirical educational sciences</td>
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<td>- Understand and critically examine information from scientific journals and media</td>
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<td></td>
<td>- Understand pedagogically relevant findings from the empirical educational sciences</td>
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In this class, students will learn concepts and skills for coping with psychosocial demands of teaching. (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks). (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).

**Gender Issues In Education and STEM**

Number of participants limited to 30.

**Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).**

Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

**Abstract**

In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.

**Objective**

- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues.
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher's work.

**Content**

Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

Prerequisites / notice

Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

**Subject Didactics and Professional Training**

**Number**

<table>
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<tr>
<th>Course Code</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>751-9020-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>W</td>
<td>6 credits</td>
<td>13P</td>
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</table>

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<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>751-9005-00L</td>
<td>Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Agricul. Sc A</td>
<td>O</td>
<td>2 credits</td>
<td>4A</td>
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**Number**

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<tr>
<th>Course Code</th>
<th>Title</th>
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<td>6 credits</td>
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<tbody>
<tr>
<td>751-9005-00L</td>
<td>Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Agricul. Sc A</td>
<td>O</td>
<td>2 credits</td>
<td>4A</td>
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</table>

**Abstract**

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

**Objective**

The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

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Autumn Semester 2021
Page 20 of 2152
Themenatische Schwerpunkte:

Lernformen:

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

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

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

---

### Agricultural Sciences TC - Key for Type

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

### Key for Hours

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

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Agricultural Sciences Master
► Major in Animal Sciences
►► Disciplinary Competences
►►► LivestockSystems

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

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

**Objective**
At the end of the course the students are able to apply, by a comprehensive understanding of the underlying mechanisms, their knowledge in various fields of ruminant science. They will be able to develop and recommend best strategies for breeding programs, feed formulation, improving forage quality, and increasing animal health. They will be trained to carry out interdisciplinary and disciplinary research at the highest level. The course Ruminant Science (FS) offered in spring has a similar structure but is complementary to this course.

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

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

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

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

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

The field of Ruminant Science will also be a part of the spring semester (special topics: Organic Ruminant Systems, Tropical Ruminant Systems, Mastitis; disciplinary courses: Cattle, Sheep and Goat Breeding, Ruminant Diseases and Prophylaxis, Ruminant Nutrition and the Environment). However both courses are organized independently.

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

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

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<th>Number</th>
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<tbody>
<tr>
<td>751-6601-00L</td>
<td>Pig Science (HS)</td>
<td>W+</td>
<td>2 credits</td>
<td>2V</td>
<td>to be announced</td>
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</table>

**Abstract**
The overall goal of the course is to provide the essential scientific knowledge of pig animal health and behaviour and of the implications for husbandry and animal welfare.

**Objective**
Students will
- understand the complex interactions of health management, behaviour and husbandry.
- be trained to understand interdisciplinary and disciplinary research.
- be able to critically analyze published research data.
- be able to present precise scientific reports in oral and written form.

**Content**
Topics:
- Understanding natural behaviour of pigs to improve their management
- Welfare challenges in pig production
- On-farm and post-mortem health assessment
- Farrowing and lactation
- Pig reproduction and associated problems
- Piglet mortality and morbidity
- Emotions
- Cognition
- Pain

There will be 1 excursion to the pig stable of AgroVet Strickhof.

**Lecture notes**
Handouts/scripts are distributed by the the lecturers.

**Literature**
Specific literature is indicated by the lecturers.

**Prerequisites / notice**
Knowledge in animal health, animal welfare and ethology is recommended but not required.

The lectures will be in English and German (depending on the lecturers)

**Number of participants limited to 20.**
Structure of the contact hour part of the course (16 h):

The course enables students to understand in detail how ruminal digestion works and how this knowledge can be applied to design optimal feeding diets using highly fibrous forages and a variety of other feeds. The students also are able to show how to modify the most important rumen microbes beneficially by nutritional means.

Introduction to both forms of presentation will be offered by the lecturer.

The preparation of the oral and written presentations takes place to a small part during the 2-h blocks and mainly outside of this time.

Lecture notes

no scriptum

Prerequisites / notice

Requirements for allocation of the two credit points:
- Theatre presentation (with handout) at the forum
- Delivery of written documents of sufficient quality
- Active participation during the presentations by the other participants

### Livestock Biology

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<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>751-7211-00L</td>
<td>Ruminal Digestion</td>
<td>W+</td>
<td>1</td>
<td>2G</td>
<td>not available</td>
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<td>Does not take place this semester.</td>
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<td>the most important aspects of ruminant</td>
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<td>nutrition: the microbial digestion in the</td>
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<td>rumen (and in the hindgut). For a</td>
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<td>comprehensive understanding of the rumen</td>
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<td>microbial ecosystem, the mechanisms of</td>
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<td>nutrient fermentation and the synthesis of</td>
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<td>microbial protein, thorough basics are</td>
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<td>laboratory exercises are included.</td>
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<td>in detail how ruminal digestion works and</td>
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<td>modify the most important rumen microbes</td>
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<td>Content</td>
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<td>2 h Introduction and blackboard exercise</td>
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<td>8 h Basic topics in ruminal digestion,</td>
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<td>lectures and group exercises:</td>
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<td>- Systematics of the microbes involved in</td>
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<td>microbial digestion</td>
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<td>- Measurement of microbial digestion</td>
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<td>- Interactions of microbes and epithelium</td>
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<td>of the digestive tract</td>
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<td>- Differences between ruminal and hindgut</td>
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<td>microbial digestion</td>
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<td>- Microbial nutrient degradation and its</td>
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<td>modification</td>
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<td>- Efficiency of microbial protein synthesis</td>
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<td>- Manipulation of the ruminal digestion</td>
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<td>4 h exercise at AgroVet-Strickhof:</td>
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<td>- Measurements of microbial digestion</td>
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<td>- Laboratory exercise with a rumen fistulated</td>
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<td>cow and a Rumen Simulation Technique</td>
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<td>2 h Final seminar</td>
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<td>the information given and to prepare either</td>
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<td>the written report or the oral presentation</td>
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<td>(cf. “Besonderes”)</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes are provided via Moodle.</td>
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<td>Literature</td>
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<td>Prerequisites / notice</td>
<td>The course is a balanced mixture</td>
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<td>of blackboard exercise, laboratory exercise,</td>
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<td>group exercise, lecture and student seminar</td>
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<td>presentation.</td>
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<td>Credit point associated with grade of either</td>
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<td>a written report or an oral presentation in</td>
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<td>the final seminar (both on a self-chosen</td>
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<td>related topic)</td>
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<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-6133-00L</td>
<td>Endocrinology and Biology of Reproduction</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>S. E. Ulbrich, S. M. Bernal Ulloa</td>
</tr>
<tr>
<td>Abstract</td>
<td>Endokrinologie und Reproduktionsbiologie der</td>
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<tr>
<td></td>
<td>Säugetiere und des Menschen (Anatomie,</td>
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<td></td>
<td>Morphologie, Physiologie, Regelmechanismen)</td>
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<tr>
<td>Objective</td>
<td>Die Studierenden erlangen das grundlegende</td>
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<tr>
<td></td>
<td>theoretische Verständnis und Fachwissen zur</td>
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<td>Endokrinologie der Reproduktion und zur</td>
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<td>weiblichen und männlichen Reproduktionsbiologie. Sie können darüber hinaus pathologische Situationen (Fortpflanzungsstörungen und deren vielfältige Ursachen in den physiologischen Kontext einordnen.</td>
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<tr>
<td>Content</td>
<td>Die Systematik der Reproduktionshormone und</td>
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<td></td>
<td>der Hormonrezeptoren wird erläutert, die Wirkungsmechanismen (Bildung; orale Bioverfügbarkeit; Elimination) erklärt. Mit diesen Grundlagen wird das Verständnis der Regulation der Fortpflanzung umfassend erörtert.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes are provided via Moodle.</td>
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<tr>
<td>Literature</td>
<td>Will be communicated at the start of the</td>
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<td>course.</td>
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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>751-7310-00L</td>
<td>Bioactive Food and Feed Components</td>
<td>W+</td>
<td>2</td>
<td>2V</td>
<td>K. Giller</td>
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<tr>
<td>Abstract</td>
<td>The course provides students with the basic</td>
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<td>knowledge to understand the connection</td>
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<td>between the structure of nutritive and</td>
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<td>non-nutritive bioactive food and feed</td>
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<td>components and their effects on the nutrient</td>
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<td>supply and health of humans and livestock</td>
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<td>as well as on the quality of animal-derived</td>
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<td>Objective</td>
<td>At the end of this course, the students are</td>
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<td>aware of food and feed as sources of</td>
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<td>different bioactive compounds. By a</td>
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<td>comprehensive understanding of the connection</td>
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<td>between bioavailability, molecular</td>
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<td>mechanisms and biological effects, they are</td>
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<td>able to apply their knowledge on beneficial</td>
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<td>and detrimental effects of bioactive food</td>
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<td>and feed components in the fields of human</td>
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<td>and animal nutrition.</td>
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</table>
The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.

Topics include:
- sources of bioactive food and feed components
- bioavailability and modification in the gastrointestinal tract
- beneficial and detrimental effects
- molecular mechanisms of biological effects
- species differences concerning metabolism and biological effects

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

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

701-0263-01L Seminar in Evolutionary Ecology of Infectious Diseases

W+ 3 credits 2G R. R. Regös, S. Bonhoeffer

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

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

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

Lecture notes
Publications and class notes can be downloaded from a web page announced during the lecture.

Literature
Papers will be assigned and downloaded from a web page announced during the lecture.

>>> Livestock Genetics

Number Title Type ECTS Hours Lecturers
751-6243-00L Breeding and conservation of Animal Genetic Resources W+ 2 credits 2V H. Signer-Hasler, C. Flury, S. Neuenschwander

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

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

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

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

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

751-6305-00L Livestock Breeding and Genomics W 3 credits 3G P. von Rohr

Abstract
Swiss routine breeding value estimation/genetic evaluation systems of cattle, pig, sheep and goats are presented with methods and evaluated traits. Examples will be demonstrated using the statistical software R.

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

Content
- basic principles of genetic evaluations
- Applied genetic evaluation in cattle (data, methods, traits, national and international genetic evaluations)
- Applied genetic evaluation in pigs (data, methods, traits)
- Applied genetic evaluation in sheep and goats (data, methods, traits)

Lecture notes
Course notes in the form of a monograph, copies of the slides and solutions to the exercise questions are available on the net.

Literature
To be announced in the lectures.

>>> Methodology Competences

>>> Methods for Scientific Research

Number Title Type ECTS Hours Lecturers

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

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

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

The tentative schedule contains the following topics:

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

Lecture notes

Handouts will be available (in English)

Literature

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

Prerequisites / notice

This course is based on the course Mathematik IV: Statistik, passed in the 2nd year and the Bachelor's course "Wissenschaftliche Datenauswertung und Datenpräsentation" (751-0441-00L)

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytics Competencies | assessed |
|                                          | Media and Digital Technologies | assessed |
|                                          | Problem-solving | assessed |

751-6127-00L Practical Course in Microscopy of Functional Histology

W+ 3 credits 6P not available

Abstract

Die "Funktionelle Histologie" beschreibt die histologischen und zytologischen Strukturen mit ihren jeweiligen Aufgaben und Wechselwirkungen innerhalb ausgewählter Organ Points. Die endokrinologisch relevanten Organe und deren Präparation werden am Beispiel des Rindes kennengelernt.

Objective

Grundlagen der Histologie; Gewebedünnsschnitte (Gefrier- und Paraffinschnitte) und deren Übersichtsfärbungen und Immunhistochemie; Fortgeschrittene Mikroskopie von Gewebedünnsschnitten; Kritische Bewertung von Physiologie/Pathologie aufgrund morphologisch-histologischer Kriterien

Content


Prerequisites / notice

In Form eines Vortrags werden den anderen TeilnehmerInnen das zugeteilte Organ bzw Gewebe bezüglich der Morphologie, Histologie und funktioneller Gesichtspunkte vorgestellt. In der Nachbereitung zum Praktikum wird ein Bericht angefertigt, in dem die Vorgehensweise (Verfahrensprotokoll), die Befunde (Ergebnisprotokoll) und die kritische Auseinandersetzung mit den Inhalten des Praktikums (kritische Beurteilung) dokumentiert werden.

Prerequisites / notice

For receiving a total of 3 Credit Points for this practical course we kindly ask you to actively take part in the practical performance. In addition, you will have to present an original research publication, address questions from your colleagues and actively participate in the discussion. The last day, you will need to pass a short written examination about the theoretical background of the techniques and results interpretation. Finally, after the course, you will have to write a lab report to be handed in at the beginning of the spring semester.

751-6129-00L Practical Course Epigenetics

W+ 3 credits 6P not available

Abstract

The practical course will comprise of lecture elements introducing the topic of epigenetics and a large amount of practical work where you will be able to perform DNA methylation analyses on your own. In particular, we will focus on DNA extraction and the estimation of global and local DNA methylation.

Objective

The competencies and aims for the course are:

- Get first hands-on experience with the experimental techniques.
- Answer a scientific question by conducting experiments.
- Obtain results of an experiment and get insight into what affects technical variation and thus influences reproducibility.
- Interpret results in an adequate manner to solve a scientific question.
- Combine results to draw an adequate conclusion.
- Present a research paper on epigenetics.

Lecture notes

You will receive in advance a selection of research papers, a document with the theoretical background of the techniques included in the course, the slides of the lessons in pdf and a detailed protocol of the work we will do.

Prerequisites / notice

For receiving a total of 3 Credit Points for this practical course we kindly ask you to actively take part in the practical performance. In addition, you will have to present an original research publication, address questions from your colleagues and actively participate in the discussion. The last day, you will need to pass a short written examination about the theoretical background of the techniques and results interpretation. Finally, after the course, you will have to write a lab report to be handed in at the beginning of the spring semester.

751-6003-00L Training Course in Research Groups (Large)

W+ 6 credits 13P S. M. Bernal Ulloa, S. Neuenschwander, H. Pausch, M. Saenz de Juano Ribes, S. E. Ulbrich
Abstract
The students will learn the conceptual and methodological background of research in the animal science groups of the Institute of Plant, Animal and Agroecosystem Science. In addition to teaching the theoretical background, the major aim of the course is to integrate the students into the research groups (on job training) and, hence, to focus on the practical application of the knowledge.

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

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

Lecture notes
None

Literature
Specific readings after enlisting in a particular research group.

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

The full integration in a research group often means to work on weekends.

The total time budget is equivalent to about 180 hours. Active participation in group meetings (discussion, presentation) and short written reports about the work conducted are required for the 6 credit points. There are no grades, it is only pass or fail.

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### Project Management for Scientific Research

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<th>Number</th>
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<tr>
<td>751-6003-01L</td>
<td>Training Course in Research Groups (Small)</td>
<td>W+</td>
<td>3 credits</td>
<td>6P</td>
<td>S. M. Bernal Ulloa, S. Neuenschwander, H. Pausch, M. Saenz de Juano Ribes, S. E. Ulbrich</td>
</tr>
</tbody>
</table>

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

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

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

**Lecture notes**
None

**Literature**
Specific readings after enlisting in a particular research group.

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

The full integration in a research group often means to work on weekends.

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

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### Tropical Cropping Systems, Soils and Livelihoods

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<tbody>
<tr>
<td>751-6001-00L</td>
<td>Forum: Livestock in the World Food System</td>
<td>W+</td>
<td>2 credits</td>
<td>1S</td>
<td>S. Meese</td>
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**Abstract**
This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.

**Objective**
In the Forum “Livestock in the World Food System”, a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society). The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion.

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

1. **Element 1. Oral presentation:** The students form small groups and are lecturers. There are chair persons (moderators) from outside of these small groups and they also head the discussion. The remaining students and lecturer are the audience.

2. **Element 2. Scientific writing:**
   - preparation of a short scientific type of paper from a result table offered by the lecturers
   - writing of a critical review of a chosen topic.

**Lecture notes**
There will be a discussion in small groups at several choosable dates.

**Prerequisites / notice**
Introductions to both forms of presentation will be offered by the lecturer.

- The preparation of the oral and written presentations takes place to a small part during the 2-h blocks and mainly outside of this time. no scriptum
- Theatre presentation (with handout) at the forum
- Delivery of written documents of sufficient quality
- Active participation during the presentations by the other participants

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### Tropical Cropping Systems, Soils and Livelihoods

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<tbody>
<tr>
<td>751-5201-10L</td>
<td>Tropical Cropping Systems, Soils and Livelihoods</td>
<td>W+</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Six, K. Benabderrazik</td>
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**Abstract**
This course has been restructured due to Covid-19 restrictions, part I (2 CP) takes place in Autumn 2021, part II (3 CP) in Spring 2022, with an excursion/fieldwork. For more information, please contact the lecturer: kenza.benabderrazik@usys.ethz.ch

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.
### Major in Plant Sciences

#### Disciplinary Competences

#### Agronomy and Plant Breeding

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<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>751-4104-00L</td>
<td>Alternative Crops</td>
<td>W+</td>
<td>2 credits</td>
<td>2V</td>
<td>A. Walter, K. Berger Büter</td>
</tr>
<tr>
<td>Abstract</td>
<td>Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.</td>
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<tr>
<td>Objective</td>
<td>Students can only join Part 2 if Part 1 was taken and validated first. A selection of 20 students for the Part 2 will be done on the basis of several elements. We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 28th 2021, justifying your motivation to enroll to this class.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Students can only join Part 2 if Part 1 was taken and validated first. A selection of 20 students for the Part 2 will be done on the basis of several elements. We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 28th 2021, justifying your motivation to enroll to this class.</td>
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<tbody>
<tr>
<td>751-3603-00L</td>
<td>Current Challenges in Plant Breeding</td>
<td>W+</td>
<td>2 credits</td>
<td>2V</td>
<td>B. Studer, A. Hund</td>
</tr>
<tr>
<td>Abstract</td>
<td>The seminar ‘Current challenges in plant breeding’ aims to bring together national and international experts in plant breeding to discuss current activities, latest achievements and future prospective of a selected topic/area in plant breeding. The topic this year will be: ‘Plant Breeding a(nd) Data Science’.</td>
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<tr>
<td>Objective</td>
<td>The educational objectives cover both thematic competences and soft skills: Thematic competences: - Deepening of scientific knowledge in plant breeding - Critical evaluation of current challenges and new concepts in plant breeding - Promotion of collaboration and Master thesis projects with practical plant breeders Soft skills: - Independent literature research to get familiar with the selected topic - Critical evaluation and consolidation of the acquired knowledge in an interdisciplinary team - Establishment of a scientific presentation in an interdisciplinary team - Presentation and discussion of the teamwork outcome - Establishing contacts and strengthening the network to national and international plant breeders and scientist</td>
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<tr>
<td>Content</td>
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#### Crop Health

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-5121-00L</td>
<td>Insect Ecology</td>
<td>W+</td>
<td>2 credits</td>
<td>2V</td>
<td>C. De Moraes, M. Mescher,</td>
</tr>
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</table>
The number of participants is limited to 30.

The aim of the course is to gain an understanding of how insects have specialised and adapted to occupy diverse environmental niches and become vital to ecosystem processes. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions and examining insect ecology in an evolutionary context.

Students will work with real-life data from the long-term measurement network Swiss FluxNet. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO₂, H₂O, N₂O and CH₄. Functional responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets and carbon sequestration. Thus, students will learn about the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

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Students will learn about the nature of alien organisms such as invasive species, biocontrol organisms and genetically modified organisms. With a particular focus on arthropods, plants and their interactions we will look at the potential threats the novel organisms pose, the benefits they provide and how both of these effects can be scientifically assessed. Students will learn how the topic of alien organisms in agriculture is intrinsically tied to policy making and regulation and get to know current examples and future challenges in research. In the last part of the course students will be able to apply the acquired knowledge in a practical exercise (case study).

Students will learn how to evaluate and present scientific Type assessed

The course focuses on the analysis and understanding of the complex and interacting processes of ecology, biogeochemistry and management of terrestrial systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Students will work with real-life data from the long-term measurement network Swiss FluxNet. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO₂, H₂O, N₂O and CH₄. Functional responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets and carbon sequestration. Thus, students will learn about the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

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

Number of participants limited to 20. Priority will be given to students in Agricultural Sciences

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

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

Lecture notes
Documents will be distributed during the lecture.

Literature
Documents will be distributed during the lecture.

Prerequisites / notice
The lecture will take place at the ETH experimental station in Eschikon Lindau. See the location of the station at: http://www.plantnutrition.ethz.ch/the-group/how-to-find-us.html

We strongly advise students who are planning to be absent for more than one week during the semester NOT to visit this course. Students must have visited the plant nutrition lectures in the 3rd and 6th semesters and the lecture pedosphere in the 3rd semester of the agricultural study program of the ETH (or bring an equivalent knowledge). This knowledge is indispensable for this 7th semester.

751-5125-00L Stable Isotope Ecology of Terrestrial Ecosystems

Number of participants limited to 20.

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

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

Content
The analyses of stable isotopes often provide insights into ecophysiological and ecological processes that otherwise would not be available with classical methods only. Stable isotopes proved useful to determine origin of pools and fluxes in ecosystems, to partition composite fluxes and to integrate processes spatially and temporally. This course will provide an introduction to the applicability of stable isotopes to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by intensive laboratory sessions, short presentations by students and computer exercises.

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
This course is based on fundamental knowledge about plant ecophysiology, soil science, and ecology in general. Course will be taught in English.
Experimental Design and Applied Statistics in Agroecosystem Science

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

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

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

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

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

Tropical Cropping Systems, Soils and Livelihoods

This course has been restructured due to Covid-19 restrictions, part I (2 CP) takes place in Autumn 2021, part II (3 CP) in Spring 2022, with an excursion/fieldwork. For more information, please contact the lecturer: kenza.benabderrazik@usys.ethz.ch

Abstract
This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

Objective
Part 1
(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess Food and energy security in tropical agroecosystems

Part 2
(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess Food and Energy Security
(6) Collaboration in international students and stakeholders

Content
Part 1 (Fall semester 2021)
This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics or agricultural economics. Students will engage in readings, discussions and exchanges on the specificities of tropical agriculture.

Part 2 (Spring 2022)
On the second module, students gain practical knowledge on field - An integral part of the course is the two-week field project in a Tropical region, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to Food and Energy Security.

Prerequisites / notice
Students can only join Part 2 if Part 1 was taken and validated first. A selection of 20 students for the Part 2 will be done on the basis of several elements. We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 28th 2021, justifying your motivation to enroll to this class.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity

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

Major in Agriculture Economics

Disciplinary Competences

--- Decision Making and Management ---

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<tr>
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<tr>
<td>363-0403-00L</td>
<td>Introduction to Marketing</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Brüggemann, F. von Wangenheim</td>
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**Abstract**

Students who take this course will increase their knowledge of marketing, its effect on consumer behavior and its role in creating long-term value. The course will introduce important concepts, frameworks and methods for marketing decision-making. A focus will be on managing customer relationships with the help of targeted promotions and data collected through digital technologies.

**Objective**

After taking the class, students will be able to:

1) Define what marketing is and describe its role at different stages of the value chain
2) Apply psychological theories to analyze behavior (e.g., purchase behavior) and identify the needs of (prospective) customers in consumer and business markets
3) Design elements of the marketing mix—e.g., develop new products and set prices—in a way that creates long-term value
4) Create an effective and efficient marketing mix that attracts and engages customers, e.g., by running targeted promotions
5) Use quantitative methods and customer data to manage relationships with customers

**Content**

The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

The structure of the course will closely follow the different steps of the value chain, i.e., the set of activities necessary for offering valuable products to customers. First, it will introduce students to psychological theories that help explain behavior, e.g., purchase behavior. It will also familiarize students with different methods from marketing research, which can be used to identify the needs of customers. Next, the course will look at the role of the marketing mix in satisfying customer needs. For example, the class will cover new product development and pricing. A focus will be on managing profitable, long-term relationships with customers. To this end, students will gain in-depth knowledge on the use of targeted promotions and marketing data to (1) attract, (2) convert and engage and (3) retain customers.

The course is designed to be “hands-on”, with opportunities to apply skills on business cases involving real-world marketing data. It will feature guest lectures from industry experts.

**Literature**


**Taught competencies**

- Domain A - Subject-specific Competencies: Concepts and Theories
- Domain B - Method-specific Competencies: Techniques and Technologies, Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving, Project Management
- Domain C - Social Competencies: Communication, Cooperation and Teamwork, Leadership and Responsibility, Self-presentation and Social Influence, Negotiation
- Domain D - Personal Competencies: Creative Thinking, Critical Thinking, Self-direction and Self-management

--- Resource Economics and Agricultural Policy ---

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<tr>
<td>751-2903-00L</td>
<td>Evaluation of Agricultural Policies</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>R. Huber, R. Finger, C. Schader</td>
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</table>

**Abstract**

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

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

Lecture notes
Handouts and reading assignments

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed

Domain C - Social Competencies
Cooperation and Teamwork
assessed

Domain D - Personal Competencies
Critical Thinking
assessed

701-1651-00L
Environmental Governance

ECTS
6 credits

W+ 2V

3G E. Lieberherr

Abstract
The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

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

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

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.

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

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

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

Lecture notes
Lecture slides and additional course material will be provided on Moodle.

Literature
We will mostly work with readings from the following books:

Prerequisites / notice
A detailed course schedule will be made available at the beginning of the semester. During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed
Decision-making
assessed
Problem-solving
assessed
Project Management
assessed

Domain C - Social Competencies
Communication
assessed
Cooperation and Teamwork
assessed
Self-presentation and Social Influence
assessed
Sensitivity to Diversity
assessed
Negotiation
assessed

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

Development and International Policy

Number
Title
Type ECTS Hours Lecturers

751-2103-00L
Socioeconomics of Agriculture
W+ 2 credits 2V S. Mann

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

Objective
Students should be able to describe the dynamics of hierarchies, markets and cooperation in an agricultural context.
Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid. The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid. Articles and book abstracts will be uploaded to a course website.

This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective. The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences. After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

Lecture notes: Assigned reading materials and slides will be available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

851-0626-01L International Aid and Development

Number of participants limited to 60

Prerequisites: Basic knowledge of economics

Abstract

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

Objective

Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid.

Content

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

Literature

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

860-0023-00L International Environmental Politics

Particularly suitable for students of D-ITET, D-USYS

Abstract

This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

Objective

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

Content

This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

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You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Lecture notes: Assigned reading materials and slides will be available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Methods in Agricultural Economics
The lectures will consist of both theoretical and practical components. In the theoretical part, we will discuss each estimation approach in detail. The lecture will present the assumptions, derivations, as well as the advantages and disadvantages of the estimation approach.

In the empirical part, we will look at simulation results using artificial data. Furthermore, we will investigate a particular estimation approach in practice using STATA.

The course will tentatively cover the following subjects:
- review of ordinary least squares (OLS) estimation
- instrumental variable estimation and two-stage least squares estimation
- seemingly unrelated regression models
- simultaneous equation models
- maximum likelihood estimation
- binary response models
- count data models
- censored and truncated regression models
- sample selection models
- treatment effect models
- static linear panel data models (random effects and fixed effects estimation)

For the theoretical portions of the lectures, we will prepare slides for in-class discussion. Slides will be distributed electronically before each lecture.

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

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

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

Literature


751-0423-00L Risk Analysis and Risk Management in Agriculture W+ 3 credits 2V R. Finger

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

You gain hands-on experience using R.

Objective
- to develop a better understanding of decision making under uncertainty and risk;
- gain hands-on experience in risk analysis and management using R
- to gain experience in different approaches to analyze risky decisions;
- to develop an understanding for different sources of risk in agricultural production;
- to understand the crucial role of subjective perceptions and preferences for risk management decisions;
- to get an overview on risk management in the agricultural sector, with a particular focus on insurance solutions
Why are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against high unemployment and inflation? The lecture provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical economic models, nonlinear dynamics and macroeconomic modeling. The course is structured along three main tasks:

- PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systems oriented management, as an approach to structure problems and to find solutions.

- PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

- PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as home work and two of these will be graded (see "Prerequisites").

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

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as home work and two of these will be graded (see "Prerequisites").
Content

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society’s resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes

The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

Literature


This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

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

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | not assessed |
| Domain C - Social Competencies | Analytical Competencies | assessed |
| | Decision-making | not assessed |
| | Media and Digital Technologies | not assessed |
| | Problem-solving | assessed |
| | Project Management | not assessed |
| Domain D - Personal Competencies | Communication | not assessed |
| | Cooperation and Teamwork | not assessed |
| | Customer Orientation | not assessed |
| | Leadership and Responsibility | not assessed |
| | Self-presentation and Social Influence | assessed |
| | Sensitivity to Diversity | not assessed |
| | Negotiation | not assessed |
| | Adaptability and Flexibility | not assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | not assessed |
| | Self-awareness and Self-reflection | not assessed |
| | Self-direction and Self-management | not assessed |

Project Management and Communication of Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-5201-10L</td>
<td>Tropical Cropping Systems, Soils and Livelihoods</td>
<td>W+</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Six, K. Benabderrazik</td>
</tr>
</tbody>
</table>

Abstract

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

Objective

Part 1

(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess Food and energy security in tropical agroecosystems

Part 2

(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess Food and Energy Security
(6) Collaboration in international students and stakeholders

Content

Part 1 (Fall semester 2021)

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, resilience to soil physics or agricultural economics. Students will engage in readings, discussions and exchanges on the specificities of tropical agriculture.

Part 2 (Spring 2022)

On the second module, students gain practical knowledge on field - An integral part of the course is the two-week field project in a Tropical region, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to Food and Energy Security.

Prerequisites / notice

Students can only join Part 2 if Part 1 was taken and validated first.
A selection of 20 students for the Part 2 will be done on the basis of several elements. We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 28th 2021, justifying your motivation to enroll to this class.

** Professional Internship **

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>751-0210-00L</td>
<td>Professional Internship</td>
<td>O</td>
<td>30 credits</td>
<td>2G</td>
<td>B. Dorn</td>
</tr>
</tbody>
</table>

*Only for MSc Agricultural Sciences*

** Abstract **


** Objective **

Im Berufspraktikum führen die Studierenden eine angemessene, anspruchsvolle Aufgabe im beruflichen Umfeld durch. Sie bearbeiten eine definierte Aufgabenstellung oder ein Projekt im Bereich der Agrarwissenschaften. Dabei wenden sie im Studium erworbene fachliche, überfachliche und methodische Kompetenzen im Arbeitsalltag an und erweitern und vertiefen diese. Zudem reflektieren sie die geleistete Praktikumsarbeit.

** Prerequisites / notice **

Der Praktikumsaufenthalt wird in der Regel im dritten Master-Semester, in jedem Fall vor Beginn der Master-Arbeit absolviert. Er kann erst absolviert werden, wenn:
- die Bachelor-Arbeit im Studiensekretariat abgegeben wurde;
- eine Einschreibung ins Master-Studium Agrarwissenschaften erfolgt ist;
- allfällige Zulassungsauflagen erfüllt sind.

** Minors **

** Agriculture Economics and Policy **

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

** Abstract **

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

** Objective **

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

** Content **

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

** Lecture notes **

Handouts and reading assignments

** Taught competencies **

- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies
- Domain C - Social Competencies
  - Communication
  - Cooperation and Teamwork
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
- Domain D - Personal Competencies
  - Adaptability and Flexibility
  - Critical Thinking
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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

** Abstract **

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

** Objective **

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

** Content **

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

** Lecture notes **

Reader with selected contents.

** Prerequisites / notice **

- Vorlesung “Management für Unternehmen der Agrar- & Ernährungswirtschaft I” in D-USYS

** Taught competencies **

- Domain A - Subject-specific Competencies
  - Techniques and Technologies
- Domain B - Method-specific Competencies
  - Analytical Competencies
- Domain C - Social Competencies
  - Communication
- Domain D - Personal Competencies
  - Critical Thinking

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-2103-00L</td>
<td>Socioeconomics of Agriculture</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>S. Mann</td>
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</tbody>
</table>

** Abstract **

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

- **Handbook of Good Research** by Jürgen Brock
- **Empirical Methods in Management**
- **Risk Analysis and Risk Management in Agriculture**
- **Dynamic Simulation in Agricultural and Regional Economics**
- **Quantification and Measurement of Risk**

### Lectures

- **Risk Analysis and Risk Management in Agriculture**
- **Dynamic Simulation in Agricultural and Regional Economics**
- **Empirical Methods in Management**
- **International Aid and Development**

### Course Details

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<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Notice</th>
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</thead>
<tbody>
<tr>
<td>751-1573-00L</td>
<td>Dynamic Simulation in Agricultural and Regional Economics</td>
<td>2 credits</td>
<td>2V</td>
<td>B. Kopainsky</td>
</tr>
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</table>
|416
- **Abstract**: In this class, students learn the basics of system dynamics and its application to agricultural and regional economic questions. In the second half of the class, students develop their own simulation model, with which they evaluate potential interventions for improving the economic as well as the ecological sustainability of food systems.

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

- **Lecture Notes / Literature**
  - Slides (will be provided during the class)
  - Articles and papers (will be provided during the class)

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<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Notice</th>
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<tbody>
<tr>
<td>751-0423-00L</td>
<td>Risk Analysis and Risk Management in Agriculture</td>
<td>3 credits</td>
<td>2G</td>
<td>R. Finger</td>
</tr>
<tr>
<td>363-0305-00L</td>
<td>Empirical Methods in Management</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Tillmanns</td>
</tr>
<tr>
<td>851-0626-01L</td>
<td>International Aid and Development</td>
<td>2 credits</td>
<td>2V</td>
<td>K. Harttgen, I. Günther</td>
</tr>
</tbody>
</table>

### Prerequisites / Notice

- Basic knowledge is expected.

- **Prerequisites / Notice**: Students should be able to describe the dynamics of hierarchies, markets and cooperation in an agricultural context.

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


- **Literature**
  - See script
Abstract
The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid.

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

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

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

Agriculture and Environment

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-5101-00L</td>
<td>Biogeochemistry and Sustainable Management</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>W. Eugster, V. Klaus</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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Abstract
This course focuses on the interactions between ecology, biogeochemistry and management of agro- and forest ecosystems, thus, coupled human-environmental systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Objective
Students will analyse and understand the complex and interacting processes of ecology, biogeochemistry and management of agroecosystems, be able to analyze large meteorological and flux data sets, and evaluate the impacts of weather events and management practices, based on real-life data. Moreover, students will be able to coordinate and work successfully in small (interdisciplinary) teams.

Content
Agroecosystems play a major role in all landscapes, either for production purposes, ecological areas or for recreation. The human impact of any management on the environment is mainly driven by effects on biogeochemical cycles. Effects of global change impacts will also act via biogeochemistry at the soil-biosphere-atmosphere-interface. Thus, ecosystem functioning, i.e., the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

Students will gain profound knowledge about biogeochemical cycles and greenhouse gas fluxes in managed grassland and/or cropland ecosystems. Responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets and carbon sequestration. Thus, students will learn about the complex interactions of a coupled human-environmental system.

Students will work with real-life data from the long-term measurement network Swiss FluxNet. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO2, H2O, N2O and CH4. Functional relationships will be identified, greenhouse gas budgets will be calculated for different time periods and in relation to management over the course of a year.

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
Prerequisites: Attendance of introductory courses in plant ecophysiology, ecology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

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

Number of participants limited to 15.

Priority will be given to students in Agricultural Sciences

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

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

Lecture notes
Documents will be distributed during the lecture.

Literature
Documents will be distributed during the lecture.

Prerequisites / notice
The lecture will take place at the ETH experimental station in Eschikon Lindau. See the location of the station at: http://www.plantnutrition.ethz.ch/the-group/how-to-find-us.html

We strongly advise students who are planning to be absent for more than one week during the semester NOT to visit this course. Students must have visited the plant nutrition lectures in the 3rd and 6th semesters and the lecture pedosphere in the 3rd semester of the agricultural study program of the ETH (or bring an equivalent knowledge). This knowledge is indispensable for this 7th semester.

751-5125-00L Stable Isotope Ecology of Terrestrial Ecosystems

Number of participants limited to 20.

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

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

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

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

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

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

Agronomy and Plant Breeding

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-4104-00L</td>
<td>Alternative Crops</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Walter, K. Berger Büter</td>
</tr>
</tbody>
</table>
Abstract  
Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.

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

Table: 
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-3603-00L</td>
<td><strong>Current Challenges in Plant Breeding</strong></td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>B. Studer, A. Hund</td>
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<tr>
<td></td>
<td><em>Number of participants limited to 15.</em></td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The seminar ‘Current challenges in plant breeding’ aims to bring together national and international experts in plant breeding to discuss current activities, latest achievements and future prospective of a selected topic/area in plant breeding. The topic this year will be: ‘Plant Breeding and Data Science’.</td>
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<td></td>
<td>The educational objectives cover both thematic competences and soft skills:</td>
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<td>- Deepening of scientific knowledge in plant breeding</td>
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<td>- Critical evaluation of current challenges and new concepts in plant breeding</td>
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<td>- Promotion of collaboration and Master Thesis projects with practical plant breeders</td>
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<td></td>
<td>- Soft skills:</td>
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<td>- Independent literature research to get familiar with the selected topic</td>
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<td>- Critical evaluation and consolidation of the acquired knowledge in an interdisciplinary team</td>
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<td></td>
<td>- Establishment of a scientific presentation in an interdisciplinary team</td>
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<td>- Representation and discussion of the teamwork outcome</td>
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<td></td>
<td>- Establishing contacts and strengthening the network to national and international plant breeders and scientist</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td></td>
<td>Interesting topics related to plant breeding will be selected in close collaboration with the working group for plant breeding of the Swiss Society of Agronomy (SSA).</td>
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</tr>
<tr>
<td>Literature</td>
<td>None</td>
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</table>

Crop Health

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-5121-00L</td>
<td><strong>Insect Ecology</strong></td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. De Moraes, M. Mescher, N. Stanczyk</td>
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<tr>
<td></td>
<td><em>The number of participants is limited to 30.</em></td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This is an introductory class on insect ecology. During the course you will learn about insect interactions with, and adaptations to, their environment and other organisms, and the importance of insect roles in our ecosystems. This course includes lectures, small group discussions and outside readings.</td>
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<td><strong>Objective</strong></td>
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<td>The aim of the course is to gain an understanding of how insects have specialised and adapted to occupy diverse environmental niches and become vital to ecosystem processes. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions and examining insect ecology in an evolutionary context.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Selected required readings (peer reviewed literature). Optional recommended readings with additional information.</td>
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<tr>
<td>751-4811-00L</td>
<td><strong>Alien Organisms in Agriculture</strong></td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>J. Collatz, M. Meissle</td>
</tr>
<tr>
<td></td>
<td><em>Number of participants limited to 30.</em></td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The course focuses on alien organisms in agriculture as well as the scientific assessment and regulatory management of their effects on the environment and agricultural production.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>Alien organisms in agriculture is a topic that receives an increasing awareness among farmers, agricultural scientists, regulators and the general public. Students of this course will learn about the nature of alien organisms, how they can affect the ecosystem, and how they can be managed.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td></td>
<td>Provided to students through Moodle</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td>Participation in the BSc course ‘Pflanzenzüchtung’ is strongly recommended, a completed course in ‘Molecular Plant Breeding’ is highly advantageous.</td>
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701-0263-01L  
**Seminar in Evolutionary Ecology of Infectious Diseases**

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

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

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

Lecture notes  
Publications and class notes can be downloaded from a web page announced during the lecture.

Literature  
Papers will be assigned and downloaded from a web page announced during the lecture.

751-4506-00L  
**Plant Pathology III**

Abstract  
Identification based on host, symptoms and micro-morphology, completed with life cycles and related control measures of the most important fungal diseases and their causal pathogens of annual and perennial crops with agricultural significance.

Objective  
The students will learn and train preparation skills for microscopy, acquire knowledge of selected diseases (identification, biology of pathogen, epidemiology and systematics) and understand the corresponding integrated control measures practiced in Swiss agriculture.

Content  
One exercise will be on an e-learning base (with computers) also to prepare the students for the final e-exam.

Lecture notes  
A script will be used on annual and perennial crops and their most important diseases. It will be updated stepwise.

Prerequisites / notice  
The course will be in German (spec. nomenclature).

Number of participants limited to 20.

Data Science and Technology for Agricultural Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-3001-00L</td>
<td>Environmental Systems Data Science</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>L. Pellissier, J. Payne, B. Stocker</td>
</tr>
</tbody>
</table>

**Objective**

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

**Objective**

The students will be able to use the software R efficiently for data analysis, graphics and simple programming

**Prerequisites / notice**

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

**Prerequisites / notice**


**Lecture notes**

The course resources will be provided via the Moodle web learning platform.
As from FS 2019, subscribing via Mystudies should *automatically* make you a student participant of the Moodle course of this lecture, which is at:
https://moodle-app2.let.ethz.ch/course/view.php?id=1518

**Prerequisites / notice**


**Lecture notes**

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

**Prerequisites / notice**


**Lecture notes**

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

**Prerequisites / notice**


**Lecture notes**

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org
### 751-5510-00L  
**Introduction to Agricultural Robotics**

**W+**  
3 credits  
2G  
S. Mintchev

**Number of participants limited to 20.**

**Abstract**  
In this course, students will learn theoretical and practical aspects of robotics. Lectures will give an introduction to how robots operate in the real world. Students will apply the concepts learned in class on educational robots to simulate a weeding task.

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

**Content**  
Robots are becoming a key technology in the transition to smart farming and in supporting the agricultural needs of the 21st century. For example, robots enable site-specific fertilization, automated weeding, or livestock herding. The course gives an overview of robotic systems, beginning with their fundamental components (e.g., sensors, actuators, locomotion strategies) and gradually scaling up to the system level, illustrating the concepts of perception, robot control, obstacle avoidance and navigation. Exercises performed with an educational robot (Thymio) will complement the theoretical lectures providing a hands-on practical experience of the challenges of using these machines. During the course, students will gradually apply the theoretical and practical knowledge they are learning. To this end, students will work in small teams (2 to 3 members) to develop a robotic solution for an agricultural task of their choice. Students will learn to translate the task into meaningful requirements for a robotic system and critically select the most appropriate components to achieve the required robotic functions. Students will periodically present and discuss the development of this "robot design" exercise during presentations and in a journal report.

**Lecture notes**  
Copies of the slides and exercises will be provided on the course web page.

**Literature**  

**Prerequisites / notice**  
No mandatory prerequisites, but it is preferable that students have a basic knowledge of computer programming.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competency</th>
<th>Taught</th>
<th>Competency</th>
<th>Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>taught</td>
<td>Techniques and Technologies</td>
<td>taught</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>taught</td>
<td>Decision-making</td>
<td>taught</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not taught</td>
<td>Problem-solving</td>
<td>taught</td>
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<td></td>
<td>Project Management</td>
<td>not taught</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>taught</td>
<td>Cooperation and Teamwork</td>
<td>taught</td>
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<td></td>
<td>Customer Orientation</td>
<td>not taught</td>
<td>Leadership and Responsibility</td>
<td>not taught</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>not taught</td>
<td>Sensitivity to Diversity</td>
<td>not taught</td>
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<td>Negotiation</td>
<td>not taught</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>taught</td>
<td>Creative Thinking</td>
<td>taught</td>
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<td>Critical Thinking</td>
<td>taught</td>
<td>Integrity and Work Ethics</td>
<td>not taught</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not taught</td>
<td>Self-direction and Self-management</td>
<td>not taught</td>
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</table>

### 701-0951-00L  
**GIS - Introduction into Geoinformation Science and Technology**

**W+**  
5 credits  
2V+3P  
M. A. M. Niederhuber

**Number of participants limited to 50.**

**Waiting list will be deleted October 8th, 2021.**

**Abstract**  
Theoretical basics and fundamental concepts of Geographic Information Science (GIS) are imparted and subsequently further elaborated with the software ArcGIS. At the end, the students will be able to independently solve basic realistic GIS problems.

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

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

One Friday is reserved for a field trip or guest speaker;
Analyze publications on long-term field experiments regarding their content on integrated nutrient management; link this information, write it

Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro


Prerequisites / notice

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

651-4031-00L Geographic Information Systems W+ 3 credits 4G A. Baltsenweiler, M. Hägeli-Golay

Number of participants limited to 60.

Abstract
Introduction to the architecture and data processing capabilities of geographic information systems (GIS). Practical application of spatial data modeling and geoprocessing functions to a selected project from the earth sciences.

Objective
Knowledge of the basic architecture and spatial data handling capabilities of geographic information systems.

Content
Theoretical introduction to the architecture, modules, spatial data types and spatial data handling functions of geographic information systems (GIS). Application of data modeling principles and geoprocessing capabilities using ArcGIS: Data design and modeling, data acquisition, data integration, spatial analysis of vector and raster data, particular functions for digital terrain modeling and hydrology, map generation and 3D-visualization.

Lecture notes
Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro

Literature


Functioning of Soil Systems

Number
751-5101-00L Biogeochemistry and Sustainable Management Does not take place this semester.

Abstract
This course focuses on the interactions between ecology, biogeochemistry and management of agro- and forest ecosystems, thus, coupled human-environmental systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical feedback mechanisms and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Objective
Students will understand and analyse the complex and interacting processes of ecology, biogeochemistry and management of agroecosystems, be able to analyze large meteorological and flux data sets, and evaluate the impacts of weather events and management practices, based on real-life data. Moreover, students will be able to coordinate and work successfully in small (interdisciplinary) teams.

Content
Agroecosystems play a major role in all landscapes, either for production purposes, ecological areas or for recreation. The human impact of any management on the environment is mainly driven by effects on biogeochemical cycles. Effects of global change impacts will also act via biogeochemistry at the soil-biosphere-atmosphere-interface. Thus, ecosystem functioning, i.e., the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

Students will gain profound knowledge about biogeochemical cycles and greenhouse gas fluxes in managed grassland and/or cropland ecosystems. Responses of agroecosystems to the environment, i.e., to climate and weather events, but also to management will be studied. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets and carbon sequestration. Thus, students will learn about the complex interactions of a coupled human-environmental system.

Students will work with real-life data from the long-term measurement network Swiss FluxNet. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO2, H2O, N2O and CH4. Functional relationships will be identified, greenhouse gas budgets will be calculated for different time periods and in relation to management over the course of a year.

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
Prerequisites: Attendance of introductory courses in plant ecology, physiology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

751-5115-00L Current Aspects of Nutrient Cycle in Agro-Ecosystems Does not take place this semester.

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

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

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

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

Number of participants limited to 15.

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

Objective
At the end of this course, participants will obtain a mechanistic understanding of why and how the speciation of phosphorus in fertilizer can affect its release to the soil solution and subsequent uptake by plants. Students will be able to use this information for the development of fertilization schemes that maximize the nutrient uptake and fertilizer efficiency of crops or pastures. During the course, participants will become familiar with the use of radioisotopes and nuclear magnetic resonance as approaches to measure nutrient availability and forms, respectively and they will know the limits of these techniques. Students will also have the opportunity to improve their laboratory and communication skills.
### 751-5125-00L Stable Isotope Ecology of Terrestrial Ecosystems

**Number of participants limited to 20.**

<table>
<thead>
<tr>
<th>Credit Hours</th>
<th>Lecture Slides</th>
<th>Literature</th>
<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 2 credits</td>
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</table>

**Abstract**

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

**Objective**

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

**Content**

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

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

**Lecture notes**

Handouts will be available on the webpage of the course.

**Literature**

Will be discussed in class.

**Prerequisites / Notice**

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

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**701-0533-00L Soil and Water Chemistry**

<table>
<thead>
<tr>
<th>Credit Hours</th>
<th>Lecture Slides</th>
<th>Literature</th>
<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 3 credits</td>
<td>Lecture slides on Moodle</td>
<td>–Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.</td>
<td>The lecture courses Pedosphere and Hydrosphere are highly recommended.</td>
</tr>
</tbody>
</table>

**Abstract**

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

**Objective**

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

**Content**

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

**Lecture notes**

Lecture slides on Moodle

**Literature**


**Prerequisites / Notice**

The lecture courses Pedosphere and Hydrosphere are highly recommended.

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

<table>
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<th>Credit Hours</th>
<th>Lecture Slides</th>
<th>Literature</th>
<th>Prerequisites / Notice</th>
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<tbody>
<tr>
<td>W 3 credits</td>
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<td>The lecture courses Pedosphere and Hydrosphere are highly recommended.</td>
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</table>

**Abstract**

The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils/ near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

**Objective**

Students are able to
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils
The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil; to explain and compare the components of soil-water potential and its effect on plant growth. This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

### Content

**Week 1**: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;

**Week 2**: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

**Week 3**: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

**Week 4**: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

**Week 5**: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

**Week 6**: Saturated water flow in soils - laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

**Week 7**: Unsatuated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow

**Week 8**: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project

**Week 9**: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow

**Week 10**: Root water uptake and transpiration

**Week 11**: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

**Week 12**: Summary of lectures; solution of old exam

**Week 13**: Written semester-end exam

**Week 14**: Short presentations of Hydrus class projects; discussion of written exam

### Literature

**Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

**701-1343-00L**

**Abstract**

Water limitation is a primary constraint on plant growth and terrestrial fluxes worldwide. In this course, the principles of water flow in soil and plants are discussed, with particular attention on the effect of drought on root water uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed.

**Objective**

The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants and to calculate plant water status for varying pedoclimatic conditions and plant traits; to critically review and present one research question in soil-plant water relations; to openly debate on the current trends in soil and plant water research.

**Content**

24.09: Introduction.

01.10: Soil water relations; Principles of soil water retention and soil water flow; Soil hydraulic properties.

08.10: Root water uptake; soil hydraulic constraints on transpiration

15.10: Rhizosphere processes and properties; root-soil contact; root hairs; mycorrhiza; rhizodeposition.

22.10: Water flow in roots and xylem; root anatomy, architecture and plasticity; cavitation.

29.10: Transpiration; Vapor Pressure Deficit; Photosynthesis; Stomatal regulation.

05.11: Soil-plant-atmospheric continuum; Below- and above-ground feedbacks; Soil and atmospheric drivers of transpiration losses.

12.11: Modelling Soil-Plant Water Relations (Concept)

19.11: Modelling Soil-Plant Water Relations (Implementation)

26.11: Plant response to drought and consequences for agriculture and forests. Open questions and introduction to seminar topics.

03.12: Group work in the class

10.12: Seminar (presentation of papers)

17.12: Seminar (presentation of papers)

24.12: Seminar (presentation of papers)

**751-5201-10L**

**Abstract**

This course has been restructured due to Covid-19 restrictions, part I (2 CP) takes place in Autumn 2021, part II (3 CP) in Spring 2022, with an excursion/fieldwork. More information, please contact the lecturer: kenza.benabderrazik@usys.ethz.ch

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

**Objective**

**Part 1**

1. Overview of the major land use systems in Tropical agroecosystems in several contexts Africa

2. Interdisciplinary analysis of agricultural production systems

3. Knowledge on methods to assess Food and energy security in tropical agroecosystems

**Part 2**

4. Hands-on training on the use of field methods, diagnostic tools and survey methods.

5. Gain practical knowledge on how to assess Food and Energy Security

6. Collaboration in international students and stakeholders
## General Crop Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-4104-00L</td>
<td>Alternative Crops</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Walter, K. Berger Bütler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.</td>
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<tr>
<td>Objective</td>
<td>During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomic features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.</td>
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<tr>
<td>751-3603-00L</td>
<td>Current Challenges in Plant Breeding</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>B. Studer, A. Hund</td>
</tr>
<tr>
<td>Abstract</td>
<td>The seminar ‘Current challenges in plant breeding’ aims to bring together national and international experts in plant breeding to discuss current activities, latest achievements and future prospective of a selected topic/area in plant breeding. The topic this year will be: ‘Plant Breeding a(nd) Data Science’.</td>
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<tr>
<td>Objective</td>
<td>The educational objectives cover both thematic competences and soft skills:</td>
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<td>Thematic competences:</td>
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<td></td>
<td>- Deepening of scientific knowledge in plant breeding</td>
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<td>- Critical evaluation of current challenges and new concepts in plant breeding</td>
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<td></td>
<td>- Promotion of collaboration and Master thesis projects with practical plant breeders</td>
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<td></td>
<td>Soft skills:</td>
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<td></td>
<td>- Independent literature research to get familiar with the selected topic</td>
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<tr>
<td></td>
<td>- Critical evaluation and consolidation of the acquired knowledge in an interdisciplinary team</td>
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<td></td>
<td>- Establishment of a scientific presentation in an interdisciplinary team</td>
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<td></td>
<td>- Presentation and discussion of the teamwork outcome</td>
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<tr>
<td></td>
<td>- Establishing contacts and strengthening the network to national and international plant breeders and scientist</td>
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<tr>
<td>Content</td>
<td>Interesting topics related to plant breeding will be selected in close collaboration with the working group for plant breeding of the Swiss Society of Agronomy (SSA).</td>
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<tr>
<td>Lecture notes</td>
<td>None</td>
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</tr>
<tr>
<td>Literature</td>
<td>Peer-reviewed research articles, selected according to the topic.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Participation in the BSc course ‘Pflanzenzüchtung’ is strongly recommended, a completed course in ‘Molecular Plant Breeding’ is highly advantageous</td>
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<tr>
<td>751-5121-00L</td>
<td>Insect Ecology</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. De Moraes, M. Mescher, N. Stanczyk</td>
</tr>
<tr>
<td>Abstract</td>
<td>This is an introductory class in insect ecology. During the course you will learn about insect interactions with, and adaptations to, their environment and other organisms, and the importance of insect roles in our ecosystems. This course includes lectures, small group discussions and outside readings.</td>
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<tr>
<td>Objective</td>
<td>The aim of the course is to gain an understanding of how insects have specialised and adapted to occupy diverse environmental niches and become vital to ecosystem processes. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions and examining insect ecology in an evolutionary context.</td>
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<tr>
<td>Lecture notes</td>
<td>Provided to students through Moodle</td>
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<tr>
<td>Literature</td>
<td>Selected required readings (peer reviewed literature). Optional recommended readings with additional information.</td>
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<tr>
<td>751-4811-00L</td>
<td>Alien Organisms in Agriculture</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>J. Collatz, M. Meissle</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course focuses on alien organisms in agriculture as well as the scientific assessment and regulatory management of their effects on the environment and agricultural production.</td>
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<tr>
<td>Objective</td>
<td>Students will understand the consequences arising from the unintentional or deliberate introduction of alien organisms into agricultural systems. They will be able to understand the concept of environmental risk assessment and be able to evaluate risk management options.</td>
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<tr>
<td>Content</td>
<td>Alien organisms in agriculture is a topic that receives an increasing awareness among farmers, agricultural scientists, regulators and the general public. Students of this course will learn about the nature of alien organisms such as invasive species, biocontrol organisms and genetically modified organisms. With a particular focus on arthropods, plants and their interactions we will look at the potential threats the novel organisms pose, the benefits they provide and how both of these effects can be scientifically assessed. Students will learn how the topic of alien organisms in agriculture is intrinsically tied to policy making and regulation and get to know current examples and future challenges in research. In the last part of the course students will be able to apply the acquired knowledge in a practical exercise (case study).</td>
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<tr>
<td>Lecture notes</td>
<td>Material will be distributed during the course</td>
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</tbody>
</table>
701-0263-01L Seminar in Evolutionary Ecology of Infectious Diseases

Abstract
Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field. This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases.

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

Lecture notes
Publications and class notes can be downloaded from a web page announced during the lecture.

Literature
Papers will be assigned and downloaded from a web page announced during the lecture.

751-5101-00L Biogeochemistry and Sustainable Management

Objective
Will be discussed in class.

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

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
Prerequisites: Attendance of introductory courses in plant ecophysiology, ecology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

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

Number of participants limited to 15.

Prerequisites: Attendance of introductory courses in plant ecophysiology, ecology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

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

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

Lecture notes
Documents will be distributed during the lecture.

Literature
Documents will be distributed during the lecture.

Prerequisites / notice
The lecture will take place at the ETH experimental station in Eschikon Lindau. See the location of the station at: http://www.plantnutrition.ethz.ch/the-group/how-to-find-us.html

We strongly advise students who are planning to be absent for more than one week during the semester NOT to visit this course. Students must have visited the plant nutrition lectures in the 3rd and 6th semesters and the lecture pedosphere in the 3rd semester of the agricultural study program of the ETH (or bring an equivalent knowledge). This knowledge is indispensable for this 7th semester.

751-5125-00L Stable Isotope Ecology of Terrestrial Ecosystems

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

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

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
This course is based on fundamental knowledge about plant ecophysiology, soil science, and ecology in general. Course will be taught in English.
The seminar concerns current aspects and research related to nutrient cycles in agro-ecosystems. The theme of the next seminar is “Integrated Nutrient Management to maximize nutrient use efficiency in productive agricultural systems: Insights from long-term field experiments”. The students will analyze and connect the results published for selected field experiments in a group work. They will present their analysis in a report and in an oral presentation. The seminar is composed by presentations of experts and of the students. The presentations will be synthesized during a final discussion.

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

The students will learn and train preparation skills for microscopy, acquire knowledge of selected diseases (identification, biology of pathogen, epidemiology and systematics) and understand the corresponding integrated control measures practiced in Swiss agriculture. Copies of the slides and exercises will be provided on the course web page.
#### Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

#### Non-Ruminant Science

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-6601-00L</td>
<td>Pig Science (HS)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>to be announced</td>
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</table>

**Abstract**
The overall goal of the course is to provide the essential scientific knowledge of pig animal health and behaviour and of the implications for husbandry and animal welfare.

**Objective**

- understand the complex interactions of health management, behaviour and husbandry.
- be trained to understand interdisciplinary and disciplinary research.
- be able to critically analyze published research data.
- be able to present precise scientific reports in oral and written form.

**Content**

- Understanding natural behaviour of pigs to improve their management
- Welfare challenges in pig production
- On-farm and post-mortem health assessment
- Farrowing and lactation
- Pig reproduction and associated problems
- Piglet mortality and morbidity
- Emotions
- Cognition
- Pain

There will be 1 excursion to the pig stable of AgroVet Strickhof.

**Lecture notes**
Handouts/scripts are distributed by the lecturers.

**Literature**
Specific literature is indicated by the lecturers.

**Prerequisites / notice**
Knowledge in animal health, animal welfare and ethology is recommended but not required.

The lectures will be in English and German (depending on the lecturers)

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**751-6243-00L Breeding and conservation of Animal Genetic Resources**

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

**Objective**

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

Learning objectives part 2:

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

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

**Prerequisites / notice**

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

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

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>751-6001-00L</td>
<td>Forum: Livestock in the World Food System</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>S. Meese</td>
</tr>
</tbody>
</table>
**Principles of Livestock Systems**

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-6243-00L</td>
<td>Breeding and conservation of Animal Genetic Resources</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>H. Signer-Hasler, C. Flury, S. Neuenschwander</td>
</tr>
</tbody>
</table>

**Abstract**

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

**Objective**

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

**Learning objectives part 2:**

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

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

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

751-6127-00L Practical Course in Microscopy of Functional Histology

W  3 credits  6P  not available

Abstract
The "Funktionelle Histologie" describes the histological and zytological structures with their respective influences on the regulation of the endocrinological processes. The endocrinology and reproduction of ruminants are presented at the example of the oviduct as a leading organ. The methodology includes the preparation of microsections, analysis of the histological structures, and the application of immunohistochemical techniques.

Objective
Grundlagen der Histologie; Gewebedünnschnitte (Gefrier- und Paraffinschnitte) und deren Übersichtsfärbungen und Immunhistochemie; Fortgeschrittene Mikroskopie von Gewebedünnschnitten; Kritische Bewertung von Physiologie/Pathologie aufgrund morphologisch/histologischer Kriterien

Content
Jeder/m Studierenden wird ein Organ zugeteilt, mit welchem sie/er sich intensiv theoretisch und praktisch auseinandersetzt. Anhand dieses Organes als rotem Faden, welches vom Schlachthof bereitgestellt und von den Studierenden selber seziert, eingebettet, geschnitten, gefärbt und mikroskopiert werden, wird die Lernziele erreicht.

Prerequisites / notice
In Form eines Vortrags werden den anderen TeilnehmerInnen das zugeteilte Organ bzw Gewebe bezüglich der Morphologie, Histologie und funktioneller Gesichtspunkte vorgestellt. In der Nachbereitung zum Praktikum wird ein Bericht angefertigt, in dem die Vorgehensweise (Verfahrenskonzept), die Befunde (Ergebnisprotokoll) und die kritische Auseinandersetzung mit den Inhalten des Praktikums (kritische Beurteilung) dokumentiert werden.

Lecture notes
You will receive in advance a selection of research papers, a document with the theoretical background of the techniques included in the course, the slides of the lessons in pdf and a detailed protocol of the work we will do.

751-6129-00L Practical Course Epigenetics

W  3 credits  6P  not available

Abstract
The practical course will comprise of lecture elements introducing the topic of epigenetics and a large amount of practical work where you will be able to perform DNA methylation analyses on your own. In particular, we will focus on DNA extraction and the estimation of global and local DNA methylation.

Objective
Die Theorie wird im Kurs im Detail vertieft und diskutiert.

Content

Prerequisites / notice
In Form eines Vortrags werden den anderen TeilnehmerInnen das zugeteilte Organ bzw Gewebe bezüglich der Morphologie, Histologie und funktioneller Gesichtspunkte vorgestellt.

Lecture notes
You will receive in advance a selection of research papers, a document with the theoretical background of the techniques included in the course, the slides of the lessons in pdf and a detailed protocol of the work we will do.

751-6305-00L Livestock Breeding and Genomics

W+  3 credits  3G  P. von Rohr

Abstract
Swiss routine breeding value estimation/ genetic evaluation systems of cattle, pig, sheep and goats are presented with methods and evaluated traits. Examples will be demonstrated using the statistical software R.

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

Content
Basic principles of genetic evaluations
Genetic evaluation in cattle (data, methods, traits, national and international genetic evaluations)
Genetic evaluation in pigs (data, methods, traits)
Genetic evaluation in sheep and goats (data, methods, traits)

Literature
To be announced in the lectures.

751-6113-00L Endocrinology and Biology of Reproduction

W+  3 credits  2G  S. E. Ulbrich, S. M. Bernal Ulio

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

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

Ruminant Science

Number Title Type ECTS Hours Lecturers
751-6501-00L Ruminant Science (HS)
W  4 credits  4G  K. Giller, M. Terranova, U. Witschi

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

Objective
At the end of the course the students are able to apply, by a comprehensive understanding of the underlying mechanisms, their knowledge in various fields of ruminant science. They will be able to develop and recommend best strategies for breeding programs, feed formulation, improving forage quality, and increasing animal health. They will be trained to carry out interdisciplinary and disciplinary research at the highest level. The course Ruminant Science (FS) offered in spring has a similar structure but is complementary to this course.
Content
Fields (contact hours)
- Introduction: 2 h
- Special topics: 20 h
  - Rumen Anatomy
  - Hohenheim Gas Test
  - Calf health
  - Reproduction Techniques
  - Fertility in Cows
  - Disciplinary topics: 32 h
    - Ruminal Digestion: 8 h
    - Ruminant Nutrition Physiology: 12 h
    - Reproduction in Ruminants: 8 h
- Lectures held by the students: 4 h

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

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

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

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

The field of Ruminant Science will also be a part of the spring semester (special topics: Organic Ruminant Systems, Tropical Ruminant Systems, Mastitis; disciplinary courses: Cattle, Sheep and Goat Breeding, Ruminant Diseases and Prophylaxis, Ruminant Nutrition and the Environment). However both courses are organized independently.

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

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

751-7211-00L Ruminal Digestion W 1 credit 1G not available

Abstract
This course broadens the knowledge in one of the most important aspects of ruminant nutrition: the microbial digestion in the rumen (and in the hindgut). For a comprehensive understanding of the rumen microbial ecosystem, the mechanisms of nutrient fermentation and the synthesis of microbial protein, thorough basics are provided. Apart from lectures, group and laboratory exercises are included.

Objective
The course enables students to understand in detail how ruminal digestion works and how this knowledge can be applied to design optimal feeding diets using highly fibrous forages and a variety of other feeds. The students also are able to show how to modify the most important rumen microbes beneficially by nutritional means.

Content
Structure of the contact hour part of the course (16 h):

2 h Introduction and blackboard exercise

8 h Basic topics in ruminal digestion, lectures and group exercises:
  - Systematics of the microbes involved in microbial digestion
  - Measurement of microbial digestion
  - Interactions of microbes and epithelium of the digestive tract
  - Differences between ruminal and hindgut microbial digestion
  - Microbial nutrient degradation and its modification
  - Efficiency of microbial protein synthesis
  - Manipulation of the ruminal digestion

4 h exercise at AgroVet-Strickhof:
  - Measurements of microbial digestion
  - Laboratory exercise with a rumen fistulated cow and a Rumen Simulation Technique

2 h Final seminar

The non-contact hour part is to comprehend the information given and to prepare either the written report or the oral presentation (cf. "Besonderes")

Lecture notes
Lecture notes are provided via Moodle.

Literature
Will be communicated at the start of the course.

Prerequisites / notice
The course is a balanced mixture of blackboard exercise, laboratory exercise, group exercise, lecture and student seminar presentation.

Credit point associated with grade of either a written report or an oral presentation in the final seminar (both on a self-chosen related topic)

751-6001-00L Forum: Livestock in the World Food System W 2 credits 1S S. Meese

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

Objective
In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society). The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion.
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two elements:

Element 1. Oral presentation: The students form small groups and are lecturers. There are chair persons (moderators) from outside of these small groups and they also head the discussion. The remaining students and lecturer are the audience.

Element 2. Scientific writing:
1. preparation of a short scientific type of paper from a result table offered by the lecturers
2. writing of a critical review of a chosen topic.

There will be a discussion in small groups at several choosable dates.

Introductions to both forms of presentation will be offered by the lecturer.

The preparation of the oral and written presentations takes place to a small part during the 2-h blocks and mainly outside of this time.

In the Forum "Livestock in the World Food System", a topic of significance for livestock agriculture is selected by the students and ECTS
H. Signer-Hasler
M. Siegrist
Forum: Livestock in the World Food System
The Forum "Livestock in the World Food System" will take place in blocks of 2 hours each. Once the general topic has been selected, it will

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

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

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

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

Safety and Quality in Agri-Food Chain

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<tbody>
<tr>
<td>751-6001-00L</td>
<td>Forum: Livestock in the World Food System&lt;br&gt;Number of participants limited to 20.</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>S. Meese</td>
</tr>
<tr>
<td>Objective</td>
<td>This forum is a platform for the critical reflection of relevant topics of livestock in the frame of the world food system comprising issues from basic knowledge to acceptance in society. The exchange is operated by scientific writing and presentation.</td>
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<tr>
<td>Learning Objectives part 2:</td>
<td>In the Forum &quot;Livestock in the World Food System&quot;, a topic of significance for livestock agriculture is selected by the students and subsequently dealt with from various angles (from scientific basis to production systems, environmental aspects and to the acceptance by society). The students learn to present a scientific subject in writing and orally to an audience and to defend the presentation in a discussion.</td>
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<tr>
<td>Content</td>
<td>The Forum &quot;Livestock in the World Food System&quot; will take place in blocks of 2 hours each. Once the general topic has been selected, it comprises two elements:</td>
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<tr>
<td>Element 1. Oral presentation: The students form small groups and are lecturers. There are chair persons (moderators) from outside of these small groups and they also head the discussion. The remaining students and lecturer are the audience.</td>
<td>Element 2. Scientific writing:</td>
<td></td>
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<tr>
<td>1. preparation of a short scientific type of paper from a result table offered by the lecturers</td>
<td>2. writing of a critical review of a chosen topic.</td>
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<tr>
<td>There will be a discussion in small groups at several choosable dates.</td>
<td>Introductions to both forms of presentation will be offered by the lecturer.</td>
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<tr>
<td>The preparation of the oral and written presentations takes place to a small part during the 2-h blocks and mainly outside of this time.</td>
<td>no scriptum</td>
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</table>

Prerequisites / notice
Requirements for allocation of the two credit points:
- Theatre presentation (with handout) at the forum
- Delivery of written documents of sufficient quality
- Active participation during the presentations by the other participants

752-2122-00L Food and Consumer Behaviour | W | 2 credits | 2V | M. Siegrist, C. Hartmann |

Abstract
This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products. The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues.

Number of participants limited to 20.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-5111-00L</td>
<td>Gene Technology in Foods</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>F. Constancias, G. Broggini, A. Greppi, F. Orelli</td>
</tr>
</tbody>
</table>

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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>751-6243-00L Breeding and conservation of Animal Genetic Resources</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>H. Signer-Hasler, C. Flury, S. Neuenschwander</td>
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</tbody>
</table>

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

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

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

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

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

Prerequisites / notice
Requirements for allocation of the two credit points:
- Theatre presentation (with handout) at the forum
- Delivery of written documents of sufficient quality
- Active participation during the presentations by the other participants

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<td>F. Constancias, G. Broggini, A. Greppi, F. Orelli</td>
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</table>
This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

This course will provide knowledge and biological background on genetically modified organisms (GMO) and food produced with the help of GMO, especially on the molecular basis of GMO constructions with emphasis on genetically modified food in Switzerland and the EU. Criteria of rationale food safety and health assessment in agriculture and food consumption will be elaborated.

Overview on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used transgenes in food as well as on GMO used for food production and their detection technologies in food; food safety assessment of GMO food; information on the legislation in Switzerland and EU-countries

Copies of slides from lectures will be provided

Actual publications from literature will be provided

Good knowledge in biology, especially in microbiology and molecular biology are prerequisites.

Some contents will be provided by registered students who will present as a group an actual publication.

This course covers the interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to processing.

Students should be able to describe and compare the major concepts/criteria used for the evaluation of the nutritional quality of food. They will apply these criteria when assessing the effects of selected processing technologies on nutritional quality. They will evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods).

The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, emerging technologies) or new formulation strategies. Possible evaluation methods for these changes (e.g. nutritional profile) will be addressed.

There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of recommended readings will be given at the beginning of the course.

The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and nutrition is expected, as well as an understanding of food processing.

The course provides students with the basic knowledge to understand the connection between the structure of nutritive and non-nutritive bioactive food and feed components and their effects on the nutrient supply and health of humans and livestock as well as on the quality of animal-derived foods.

Students should be able to:
- describe and compare the major concepts/criteria used for the evaluation of the nutritional quality of food
- apply these criteria when assessing the effects of selected processing technologies on nutritional quality
- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods)

The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.

Topics include:
- sources of bioactive food and feed components
- bioavailability and modification in the gastrointestinal tract
- beneficial and detrimental effects
- molecular mechanisms of biological effects
- species differences concerning metabolism and biological effects

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

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

The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

At the end of the course, the students are aware of food and feed as sources of different bioactive compounds. By a comprehensive understanding of the connection between bioavailability, molecular mechanisms and biological effects, they are able to apply their knowledge on beneficial and detrimental effects of bioactive food and feed components in the fields of human and animal nutrition.

The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.

Topics include:
- sources of bioactive food and feed components
- bioavailability and modification in the gastrointestinal tract
- beneficial and detrimental effects
- molecular mechanisms of biological effects
- species differences concerning metabolism and biological effects

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

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

The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

Elective courses can be chosen from the entire course programme of the ETH Zurich as well as from the course programme of the University of Zurich.
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

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

After the course, students will be able to critically examine and select appropriate robotic solutions for agricultural applications.

Robots are becoming a key technology in the transition to smart farming and in supporting the agricultural needs of the 21st century. For example, robots enable site-specific fertilization, automated weeding, or livestock herding.

The course gives an overview of robotic systems, beginning with their fundamental components (e.g., sensors, actuators, locomotion strategies) and gradually scaling up to the system level, illustrating the concepts of perception, robot control, obstacle avoidance and navigation. Exercises performed with an educational robot (Thymio) will complement the theoretical lectures providing a hands-on practical experience of the challenges of using these machines.

During the course, students will gradually apply the theoretical and practical knowledge they are learning. To this end, students will work in small teams (2 to 3 members) to develop a robotic solution for an agricultural task of their choice. Students will learn to translate the task into meaningful requirements for a robotic system and critically select the most appropriate components to achieve the required robotic functions. Students will periodically present and discuss the development of this "robot design" exercise during presentations and in a journal report.

Copies of the slides and exercises will be provided on the course web page.

No mandatory prerequisites, but it is preferable that students have a basic knowledge of computer programming.

Class size limitation to 20 students.

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

The aim of this lecture series is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html
Objective

Students know the elements of agroecology and are able to critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches. Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions.

Content

Organization of the lecture:

The lecture series will take place in the fall semester of ETH Zurich, starting in the week of September 20, 2021 and lasting until December 17, 2021. During this period, the lecture will take place once a week, on Tuesdays from 18:00-20:00 (CEST/CET).

Each lecture will be organized in an online format and will be set up in two parts consisting of a public and a student lecture:

At the end of the lecture series, the course will be evaluated with the students.

Public lecture part (virtually via Zoom webinar):

The public lecture (18:00-19:00 CEST/CET) will take place virtually via this Zoom webinar: https://ethz.zoom.us/j/64352765873.

While most public lectures will take one hour, the last public lecture on “Agroecology, The Way Forward”, on Tuesday, 7th December 2021, will last 90 minutes.

Student’s lecture part (exchange with course instructors online via zoom):

The student’s lecture (19:15-20:00h CEST/CET) will take place online via a normal Zoom call: https://ethz.zoom.us/j/61315399346.

For further details, please refer to the Moodle-page of this course: https://moodle-app2.let.ethz.ch/course/view.php?id=15210

Lecture notes

On the Moodle-page you can find some pre-readings for the course.


Prerequisites / notice

The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.

The Sustainable Development Goals Book Club

W+ 2 credits  B. B. Pearce, J. Ghazoul

Abstract

The ETH Sustainable Development Goals Book Club is a colloquium for Bachelor students within and outside of Department of Environmental Systems Science centered around the discussion of themes from a single book, with the aim of fostering interdisciplinary, intellectual and critical exploration of the scientific and societal complexities related to the Sustainable Development Goals.

Objective

The aims of this course are to:

- Create an interdisciplinary approach to understanding key concepts of sustainable development and the SDGs
- Create solidarity through a cultural of intellectual exchange at ETH Zurich
- Create a common object of intellectual reference for students with different disciplinary interests to enable diverse ways and modes of thinking

Content

The course is similar to 701-0019-00L Readings in Environmental Thinking with the following differences:

- Targeted at Bachelor’s students (especially first and second year, but open to all) within and outside of the department.
- All participating students will read one book whose themes will be the basis for discussions.
- These discussions, taking place both online and in-person, will be moderated by the main lecturers of the course and discussed by additional professors from within and outside of D-USYS.
- Each discussion will be based on a chapter of a book, always linked to a particular aspect of the SDGs.
- The modes of discussion will vary in length and form, ranging from the traditional, sit-down meeting, to a Twitter book club format (as already pioneered and popularized by author Robert MacFarlane).
- Both students and professors will lead the discussions alternatively.
- Each discussion session will result in a visual output or another shareable output that will be developed by a student or group of students.

Literature

TBD

Could be one of the books already used in 701-0019-00L Readings in Environmental Thinking (Silent Spring, The Sand County Almanac, Collapse, etc.).

Other possibilities:

- Thinking in systems
- Limits to Growth
- Operating Manual for Spaceship Earth
- Small is Beautiful
- For the Common Good
- Factfulness
- The Prize: The Epic Quest for Oil, Money and Power (history of the global petroleum industry from 1850s-1990)

Prerequisites / notice

none

Master’s Thesis

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-1030-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Lecturers</td>
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</table>

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

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

Abstract

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

Objective

The independent writing of a scientific paper/thesis

Agricultural Sciences Master - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Notice</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Suitable for doctorate</td>
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### Key for Hours

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<th>Key</th>
<th>Type</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**
- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Applied Geophysics Master

Courses at ETH Zurich only take place in Spring Semester.

### Applied Geophysics Master - Key for Type

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<tr>
<th>Key</th>
<th>Name</th>
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<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
<td>Suitable for doctorate</td>
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### Key for Hours

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<tr>
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**ECTS**

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</thead>
<tbody>
<tr>
<td>052-0603-00L</td>
<td>Structural Design I</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>P. Block, J. Schwartz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Determination of internal forces and description of structural behaviour of mixed arches and cable structures, of truss systems, beams, slabs, panels and frames using method of graphical statics as well as dimensioning of these structural systems. Structural behaviour of columns. Discussion of reference buildings and illustration of interplay of structural system and architectural intention.</td>
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<tr>
<td>Objective</td>
<td>Awareness of the most important structural systems. Understanding of the interplay of load and form. Estimation of the inner forces and dimensioning of elements.</td>
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<tr>
<td>Content</td>
<td>After a general introduction of basic concepts, structural systems such as cable and arch structures will be analyzed with the help of graphic statics. The students will learn to understand the flow of forces in a structural system in relation to the system's form. They will be able to modify this force flow and give dimension to the structural components.</td>
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<tr>
<td>Lecture notes</td>
<td>All concepts, approaches and methods will be introduced in the weekly lectures and practiced in subsequent exercises.</td>
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</tbody>
</table>
| Literature    | on eQuilibrium
  "Script Tragwerksentwurf I/II"
  http://www.block.arch.ethz.ch/eq/course/4?lang=en
  A printed version can be bought at the chair of Structural Design Prof. Schwartz for sFr. 55.-. |
| "Rule of thumb structural design" (Philipp Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2013, ISBN: 978-3-421-03904-0) |
| Further learning material: |
| 052-0703-00L  | Sociology I         | W    | 2 credits | 2V   | C. Schmid, I. Apostol, N. Bathla, A. Hertzog-Fraser |
| Abstract      | Sociology I investigates the relation between social developments and the production of the built environment from a macro-sociological point of view. It examines central aspects of social change, historical and contemporary forms of urbanization, and typical examples of models of urbanization. |
| Objective     | This series of lectures should enable students to comprehend architecture in its social context. |
| Content       | Sociology I deals with the macro-sociological point of view, and investigates the relation between social developments and the production of the built environment. In the first part central aspects of social change are examined, in particular the transition from Fordism to Neoliberalism and the interlinked processes of globalization and regionalization. The second part deals with historical and current forms of urbanization. Among other aspects, it focuses on the changed significance of the urban-rural contradiction, the processes of suburbanization, periurbanization, and planetary urbanization; the formation of global cities and metropolitan regions; the development of new urban configurations in centres (gentrification) and in urban peripheries (edge city, exopolis, new urban intensity). In the third part these general processes are illustrated by typical models of urbanization: Manchester, Chicago, Los Angeles, Paris and Zürich. |
| Literature    | A detailed collection of original texts will be distributed. |
| Literature    | A detailed collection of original texts will be distributed. |
| 052-0901-00L  | Building History I  | O    | 2 credits | 2V   | S. Holzer     |
| Abstract      | History of building from classical antiquity to modernity: building types, constructions, forms, with particular reference to functional issues such as flexibility of use, statics, durability. This is not a mere history lecture, but an important part of the basic introduction into construction. |
| Objective     | Participants know the fundamentals of building history, including landmark monuments of each era, key historic constructions and forms. They are able to "read" a historic building and to relate it to building history. They are aware of the variety of historic building constructions. |
| Content       | Building History I covers the period from classical Greek antiquity to Gothic architecture. The principal topics include construction issues such as Greek megalithic building, Roman mortar-and-rubble construction, and Gothic rationalism of vaulted architecture. |
| Literature    | Within the Vitruvian and Albertian triad of firmitas, utilitas and venustas, we focus on the first two topics, whereas the last topic (deciphering the "meaning" of architecture) stands at the heart of the "architectural history" lectures. The present lecture contributes essentially to deepening knowledge about historic constructions, an indispensable precondition for building within existing fabric. |
| Lecture notes | Please keep a tight record of manuscript notes yourself. Lecture notes to some topics will be provided. pdf of lecture slides will be on line before each lecture. |
| Literature    | Will be announced during the lectures. |
The lecture introduces the most common building materials: concrete, steel, masonry, and timber, but also clay, glass, and polymers. It focuses on their ecological aspects, such as availability of raw materials, efforts for production, and the emission of hazardous substances. The lecture also covers the disposal and recycling of materials.

For the course 'History and Theory of Architecture I-II', students will rely on assisted self-study to acquire basic knowledge of the history of architecture in Europe. Printed copies of the course scripts will also be available for purchase.

During the course, students are invited to make use of it for their study, and attendance is compulsory.

In addition to the main lectures, the course 'History and Theory of Architecture I-II' will also include a series of seminars, called 'Small Narratives'. These seminars are meant to widen the scope of the programme by exploring case studies, such as buildings and ruins in Zurich, which relate and contribute to the content of the course. While content of the 'Small Narratives' seminars is not part of the exam, students are invited to make use of it for their study, and attendance is compulsory.

The course 'Fundamentals of the History and Theory of Architecture I-II' aims to explore and develop basic methods and strategies to research the history of art and architecture. It consists of four parts, each developed under one of the four Chairs of the gta, and each dealing with a particular area of study in the field of architecture and art history. The course will consist of four different exercises and tasks, carried out under the supervision of each of the four Chairs throughout the year:

1. Architecture and books (M. Delbeke)
2. Architecture and media (L. Stalder)
3. Architecture and art (P. Ursprung)
4. Urbanism and the Commons (T. Avermaete)

For the course 'History and Theory of Architecture I-II', students will rely on assisted self-study to acquire basic knowledge of the history of architecture in Europe.
Abstract
The means and potentials in the field of urban planning and design are pointed out from different perspectives in order to shape the city in the sense of a future-proof and humane environment. To this end, the basic principles are explained and concrete methods of urban design are presented.

Objective
The goal is to provide students with a broad systemic basic knowledge, that enables them to synthesize and evaluate complex urban design and planning problems.

Content
The lecture series imparts basic knowledge in urban planning and design. Pressing questions and main topics of contemporary urban design practice and theory will be addressed. The focus is on illustrating the richness of relationships as well as the potential of the discipline and its handling in everyday urban planning and design practice.

Lecture notes
There is no script to the lecture series. The lectures are recorded on video and made available online on http://www.video.ethz.ch/lectures.html a few days after each lecture.

Literature
At the end of the year course a reader with secondary literature will be made available for download.

Prerequisites / notice
Further Informations: https://www.staedtebau.arch.ethz.ch

052-0605-00L Mathematics and Programming I

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and Construction I</td>
<td>O</td>
<td>8 credits</td>
<td>4V+10G+2U</td>
<td>A. Deplazes, D. Mettler, D. Studer</td>
</tr>
</tbody>
</table>

Abstract
This course introduces computational design and teaches how design can be modeled and materialized using digital technology. Participants learn to use the computer strategically, thoughtfully, and sensitively within the design process. With the “digital literacy” acquired in this course, they develop an understanding of the potential of a digital building culture.

Objective
To systematically harvest the potential of the computer in their work processes, architects need an insight into the fundamental principles of information technology. The course, students learn the concepts, methods, and instruments of computational design. By the end of the two semesters, students will have mastered the basics of 3D modeling techniques, parametric design, programming code for Computer-aided-design (CAD), and digital prototyping. The acquired knowledge qualifies students to use the computer as a unique instrument to model their designs. Participants also learn to apply CAD and programming code creatively and productively in planning, design, and construction.

Specifically, the learning goals are:
- Critical understanding of the possibilities of information technology in design
- Acquiring an overview of the mechanisms and types of CAD systems and digital building models
- Gaining knowledge of the basic principles of computational geometry
- Applying visualization techniques and creatively using various digital media
- Learning concepts and application of parametric design.
- Being able to integrate computer-aided analysis and optimization methods in design-process
- Understanding the principles of digital process chains from design to production
- Strategically using visual programming code
- Reading, understanding, and adapting programming code within CAD software.

Content
Architecture is no longer conceivable without information technology. The planning, construction, operation, and ultimately the nature of buildings are increasingly influenced by digital technology. The digital is omnipresent both in the work of architects and in our built environment itself.

The courses Computational Design 1 and 2 offer an introduction to the character, challenges, and possibilities of digital technology in architectural design. The lectures will discuss the topics of digital building models and data, computational geometry, digital fabrication, machine intelligence, and mixed reality.

In this course, students will practice digital modeling processes and related techniques. The spectrum of exercises includes manual modeling, visual programming, and programming code within CAD software. Students learn to read, understand and adapt this code. In addition, the courses will provide insights into the nature and handling of different digital media formats, from real-time rendering to mixed reality.

Topics discussed within the lectures:
- CAD - background, and developments
- On the nature of digital models and data
- Architectural geometry
- Computational geometry
- Parametric and generative creation of models
- Computer-aided analysis and optimization of models
- Artificial intelligence and architectural models
- Materialization of digital models
- Mixed reality

Course Structure
The course consists of theoretical lectures, practical tutorials introducing technical concepts, and exercises supported by tutors. Participants can find updated and detailed information on Moodle, which is the learning platform for the course.

Subjects with Semester Grade

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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>052-0501-00L</td>
<td>Design and Construction I</td>
<td>O</td>
<td>8</td>
<td>4V+10G+2U</td>
<td>A. Deplazes, D. Mettler, D. Studer</td>
</tr>
</tbody>
</table>

Designing and constructing will be understood to be a complementarily complementary offer. The content and methodical foundations of design and construction are taught and deepened through lectures and exercises.

Abstract
Designing and constructing will be understood to be a complementarily complementary offer. The content and methodical foundations of design and construction are taught and deepened through lectures and exercises.

Objective
Understanding and dominating the methodology of designing and constructing.

Content
Lectures and exercises to achieve the methodology and ability of designing and constructing.

Lecture notes

Literature
Further Informations: https://www.staedtebau.arch.ethz.ch

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To introduce students to the history and theory of architecture, the course has three objectives. Students are enabled to integrate essential characteristics of structural systems made out of reinforced concrete or steel into their architectural design. Normally, one would expect this course to teach students how to draw architecture while using computers. This course does not because it is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Attendance in the lecture ‘Thinking and Speaking about Art’. Elaboration of a self-contained artistic work in the framework of the group mentorates. (Emphasis of grading for the final semester grade: 3/5 final presentation, 1/5 written project-conception, 1/5 drawing examination in free and perspective drawing).

Objective
In the HS21, students prove artistic thinking and practise and develop their knowledge in a mentored course with an independent artistic work.

Content
Attendance in the lecture ‘Thinking and Speaking about Art’. Elaboration of a self-contained artistic work in the framework of the group mentorates. (Emphasis of grading for the final semester grade: 3/5 final presentation, 1/5 written project-conception, 1/5 drawing examination in free and perspective drawing).

Examining Block 1

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0607-00L</td>
<td>Structural Design III</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>J. Schwartz, P. Block</td>
</tr>
<tr>
<td>Abstract</td>
<td>After a review of essential facts from the first year the course will be examined the interplay of architectural concept and structural system by analyzing buildings of exemplary quality. The focus will be on the integration of specifics of structural systems made out reinforced concrete or steel into architectural design.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students are enabled to integrate essential characteristics of structural systems made out reinforced concrete or steel into their architectural design.</td>
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</tr>
<tr>
<td>Content</td>
<td>After a review of essential facts from the first year the course will be examine the interplay of architectural concept and structural system by analyzing buildings of exemplary quality. The focus will be on the integration of specifics of structural systems made out reinforced concrete or steel into architectural design.</td>
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</tbody>
</table>

| 052-0805-00L | History and Theory of Architecture III | O    | 2 credits | 2V    | L. Stalder |
| Abstract     | This two-semester course is an introduction to the history of architecture from the Second Industrial Revolution in the 1850s to the Oil Crisis in the 1970s in Europe. Students will be able to identify the “things”—technical objects and ensembles—that transformed architecture, and to relate them to the technical, scientific, and cultural concerns that introduced them as key features of modernity. |      |      |       |                  |
| Objective    | To introduce students to the history and theory of architecture, the course has three objectives. First, students will be able to identify the “things” that transformed architecture in modernity, and the crucial events, buildings, theories, and actors that characterize their history. |      |      |       |                  |
| Content      | The course proposes a new approach to the study of the history and theory of architecture in Europe during modernity. It focuses less on single architects or their buildings, and more on those “things” that have brought profound transformations in the built environment and daily life over the last 200 years, such as the revolving door, the clock, and the partition. |      |      |       |                  |

| 052-0635-00L | Mathematical Thinking and Programming III | O    | 2 credits | 2V    | L. Hovestadt |
| Abstract     | An introduction to information technology for architects. It is not about the HOW, but rather about the WHAT, not about virtuosity when dealing with digital tools, but rather about understanding coding. Not about pragmatism, but rather about literacy. It forms the basis of digital architectonics, the art of joining, which needs to be cultivated with care, prudence and patience. |      |      |       |                  |
| Objective    | Normally, one would expect this course to teach students how to draw architecture while using computers. This course does not because digital architectural models are not drawn, but encoded. |      |      |       |                  |

In the current discussion about building information models (BIM), we see how blocked the situation can become when one draws architecture digitally. Today, digital models are a tedious ‘minefield’ with hundreds of gigabytes of data of all kinds. A digital model as code, however, is lightweight, compact and fast – a sparkling crystal, like poetry.

Specific reference is made to the history of architecture in conjunction with mathematics and philosophy. The essential tool of the trade is the lambda calculus in the implementation of Mathematica. The information technology interconnection of all digital media will be presented: text, image, graphic, model, animation, film, audio and the corresponding software. Current issues will be discussed: Internet, Internet of things, cryptography, privacy, big data, machine intelligence, building information models, responsive cities, smart homes, robotics, energy and logistics. Current and historical modelling processes will be worked on.
The Mechanics of Digital
Introduction and overview on folding
Calculus
Text and numbers
Lists and colours
Pictures and films
Cryptography and communication
Rules and graphs
Graphics and Animation
3D models
Solid models
Music and sound

The Big Plenty
Parsers
Databases
Machine intelligence
Many images
Many texts
Many drawings
Many models
Smart buildings
City and country
On the Internet of Things

A Digital Archaeology of Architecture
The geometry of Euclid
The architecture of the Greeks
The arithmetic of Ptolemy
The architecture of the middle ages
The geometry of Descartes
The architecture of the Renaissance
The arithmetic of Lagrange
The architecture of the Enlightenment
The algebra of Boole
The architecture of the classical period
The theory of categories
The architecture of the 20th century

The Digital Architectural Model
Architecture and poetry
The perspective model
The probabilistic model
The crystal
The hybrid
The continuum
The Oikos
The model concept 1920
The model concept 1950
The model concept 1980
The model concept 2010
Brand and style

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-8009-00L</td>
<td>Building Physics II</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>J. Carmeliet, M. Ettlin, A. Rubin</td>
</tr>
<tr>
<td>Abstract</td>
<td>Moisture related problems are common in buildings leading to costly damage and uncomfortable indoor environments. This course aims at providing the necessary theoretical background and training in order to foresee and avoid these problems.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>to develop a basic understanding of mass transport and buffering to become aware of potential moisture-related damage and health risks to learn how to (i) design building components and (ii) assess their hygrothermal performance</td>
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<td></td>
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</tr>
<tr>
<td>Content</td>
<td>• hygrothermal loads • conservation of mass (dry air, water vapor, liquid water) • moist air: constitutive behavior, transport, potential problems and solutions • liquid water: constitutive behavior, transport, potential problems and solutions • exercises</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts, supporting material and exercises are provided online via Moodle.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Prior knowledge of “BP I: heat” is required.</td>
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</tbody>
</table>

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<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>052-0801-00L</td>
<td>Global History of Urban Design I</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>T. Avermaete</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.</td>
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<tr>
<td>Objective</td>
<td>The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.</td>
<td></td>
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</tbody>
</table>
Content

In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

01: The History and Theory of the City as Project
02: Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
03: The Idea of the Polis: Rome, Greece and Beyond
04: The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization
07: The City of Labor: Company Towns as Cross-Cultural Phenomenon
09: Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
10: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
11: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

Lecture notes

Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

Literature

There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

Prerequisites / notice

A list of further recommended literature will be found within each chapter of the reader (Skript).

Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

Examination Block 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0807-00L</td>
<td>History and Theory of Architecture V</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>P. Ursprung</td>
</tr>
</tbody>
</table>

Objective

The course target is to let the students gain a overview of a line of formative occurrences, works of art, buildings and theories from the early nineteen-seventies. The students should become sensitive for questions and problems in the field of history and theory and they should increasingly be able to relate their own praxis with historical relations.
Content
The two-semester course offers an introduction to the history of modern and contemporary art and architecture since ca. 1970. Motivated by questions of the current discourse, central topics and exemplary works of art and architecture are discussed. Concepts such as “history”, “memory”, “experience”, “research”, “nature”, “diversity” or “surface” are used to focus on specific historical developments and connections. Art and architecture is considered as a field of cultural change as well as an indicator of social, economic, and political conflicts which in turn helps to understand historical dynamics.

Lecture notes
A video documentation of the lecture class is available.
https://video.ethz.ch/lectures/d-arch/2019/autumn/052-0807-00L.html

Literature

Philip Ursprung, Der Wert der Oberfläche, Essays zu Kunst, Architektur und Ökonomie, Zürich, gta Verlag, 2017.

052-0651-00L Building Process I

Abstract
The building process is the main focus of this lecture series. The process is understood as a sequence of criteria in time. Topics: Acquisition and building law, building economics and sustainability strategies, participants and their services, construction and planning organization.

Process thinking and a look at neighbouring countries complement the series.

Objective
Alongside a discussion of the basic principles, trends and terminologies, a closer look will be taken at each topic using case studies that investigate currents in new as well as those relevant in terms of architecture and urban design. Active participation as well as interdisciplinary and process-oriented thinking on the part of students is a prerequisite.

Content
The building process is the main focus of this lecture series. The process is understood as a sequence of criteria in time. Topics: Acquisition and building law, building economics and sustainability strategies, participants and their services, construction and planning organization.

Process thinking and a look at neighbouring countries complement the series.

At the end of the semester, the Chair will provide literature and texts available for download as pdfs. These allow a more in-depth understanding of the lecture material.

052-0705-00L Energy and Climate Systems I

Abstract
The first semester of the annual course focuses on physical principles, component and systems for the efficient and sustainable heating, cooling and ventilation of buildings on different scales and the interaction of technical systems with architectural and urban design.

Content
1. Introduction and overview
2. Heating and cooling systems in buildings
3. Ventilation

Lecture notes
The slides of the lecture serve as lecture notes and are available as download.

A list of relevant literature is available at the chair.

052-0659-00L Architectural Technology V

Abstract
The lecture series explores the correlation among intentions of design, architectonic expression and construction premises. These critical areas or aspects of study, which are presented with selected projects, their respective theoretical backgrounds and historical development, are pluralistically associated and brought into relation with varying contemporary opinion.

Objective
The lecture series focuses on the physical principles and technical components of renewable and sustainable energy and energy supply of buildings. A special focus is on the interrelation of supply systems and architectural design and construction. Learning and practicing methods of quantifying demand and supply allows identifying parameters relevant for design.

Content
The different themed parts of structural design, building shell and knowledge of material get connected with architectural design in practice and reflected in the wider context of architectural theory. The intention is to consolidate the understanding of the connection between structure, process and formal appearance and expression in the architecture of the 20th century.

Lecture notes
The brochures published by the chair offer additional help. Knowledge of these brochures and their key subjects is recommended for the exam. The brochures can be ordered at the chair after the last lecture before the examination. However, the subject matters of the brochures and the lectures are not identical, the brochures provide information for a deeper understanding of the lectures. Apart from additional articles written by the chair, the brochures are composed of three modules: Project documentation, crucial texts on the work reception as well as theoretical articles about the particular thematic priorities by various authors. Concerning their content these anthologies allow insights into a wide range of theories, lines of reasoning and fields of research up to diverging points of views of specific problems.

052-0609-00L Architectural Technology V

Abstract
The lecture series explores the correlation among intentions of design, architectonic expression and construction premises. Each lecture is focused on individual themes, as for example, the application of certain materials (glass, or natural stone), of particular construction systems (tectonic, hybrid) or design generators (grids, series) and alternatively the search for a definable, tangible architectural expression (vernacular architecture, ready-mades). These critical areas or aspects of study, which are presented with their respective theoretical backgrounds and historical development, are pluralistically associated and brought into relation with varying contemporary opinion. The yearlong lecture cycle is comprised of twenty individual lectures, in which the majority of projects being analyzed date from the last few decades.
The time spent in the home office has led, among other things, to the accumulation of trillions of bytes. The question of storage arises, J. De Vylder, HS21

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</thead>
</table>

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
- The time spent in the home office has led, among other things, to the accumulation of trillions of bytes. The question of storage arises almost automatically. Starting from historical architectures of storage in Switzerland (HS), we discuss social, political and ecological questions of contemporary globalised flows of goods and data (FS) and try answer through an architectural design.

Objective
- HS21 Ability to systematically analyse buildings from different eras and describe them photographically. The study and understanding of architectural rules, qualities and principles by means of graphic representations such as axonometries, plan representations with shadows and colours, but also photographs and models.

Content
- Ideal Architecture: Storage
  - We understand the issue of storage space as an urgent and constant problematic for all human societies in all historical periods. Form the prehistoric jars to the city of Delphi, where the ancient Greeks stored for the first time in history of Europe written documents and personal belongings. From the primitive caves to the Knossos palazzo, from the roman corn warehouses to the Nevada desert, where the hidden side of our cloud society lies with his enormous amount of space used for data storage.

- The act of storing something has to do with the issue of the ‘standard’ measure. Every epoch and every society culturally defines what their standards are, based on the very necessity of their historical time, and so the architecture of the storage space adapts itself to the ever-changing standards and thus evolves. For many periods the most import-ant conventions about storing were derived from the human body. From the weight a healthy person can lift to the way a hand reaches for an object, the body conditions storage.

- To categorize the things our society stores, is as vast as the society itself. Along most Swiss train tracks, one can observe form de-signed to hold materials in different consistencies. From liquid to aeriform to solids, from bulldozed bulk freight to stacked blocks, the physical forces demonstrate the movement and storing.

- In this semester we will look closely at the architecture of storage in Switzerland. By means of fieldwork, drawing, reading, discussion and designing we will search for the ideal in storage and propose a collection of the most interesting storage buildings. We believe that these buildings, in addition to being a crucial part of any functioning of society, possess an underappreciated beauty, and that through typological mapping have the potential to shed light on the mechanism of the built world.

- SS22 REAL ARCHITECTURE: SPACE OF ACCUMULATION

  Accumulation describes the gradual gathering of elements. It is the law by which many great things operate, such as civilization, history, economy and not least the formation of planets. Architecture is also subject to the law of accumulation, as buildings do not appear in an instant, but are gradually put together on the building site. What are the pyramids if not an accumulation of stones? One possible answer would be to say that they are storage; an architectural response to accumulation as old as time itself. Is the traditional storage still valid today? What can spaces of accumulation mean for architecture?

  With the increased focus on accumulation of capital, goods and data in today’s society, you’d think that spaces of accumulation would be an essential part of our daily lives. Instead it is suspiciously missing from the public imagination, hidden away as something necessary but unsightly. It’s true that the complexity and scale of accumulation can be unnerving and as the saying goes: you don’t want to know how the sausage is made. Nevertheless, could it be necessary to understand the sausage for a sustainable future?

- In our studio, using the knowledge from the previous semester on the ideal storage, we will combine the ideal and the real in order to speculate about how recycling meets tomorrow’s space of accumulation, because we believe that answering the question about the accumulation of the future means implicitly linking architecture to the necessities and urgencies of the world to come.

Literature
- Book recommendation BUK I - IV: "Construction";
- A reference work on contemporary construction
- German or English
- 360 pages, 171 images, 20 color images, texts
- ISBN 978-3-0356-2225-6
- Online reference source: https://www.hochparterre-buecher.ch/ Konstruktionen.html
Working in groups only.

Critiques: 12./13.10., 9./10.11. and 30.11./1.12;
Costs: CHF 100.-- (besides seminar week).

Prerequisites / notice

Taught competencies

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

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

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

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

Taught competencies

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

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

Domain C - Social Competencies
- Communication
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- Sensitivity to Diversity

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

Architectural Design III: House Behaviorology in Switzerland (Kaijima)

Teaching languages are English and German.

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php). Students who do not wish to change the design class must not enrol.

Project grading at semester end is based on the list of enrolments on 2.11.21 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
The course focuses on a house and housing design in and around Zurich. Through the analysis of existing houses, including their users and locations, and by designing a housing complex, students learn about basic principles of housing design and the knowledge about issues of private/public, common spatial design for urban ecology.

Objective

Knowledge:
- Design research by actor network drawing (Week 1-4)
- Learning about actor networks
- Learning basic research methods (collection and analysis of data and information)
- Understanding a building design by actor networks
- Visualizing a building by actor network drawing
- Finding design principles by drawing

- Principles of house and housing design (Week 5-9)
- Understanding the form of a house by understanding the behavior of climate, material, users, elements and typology
- Learning about dimensions in a house and housing design
- Learning about the architectural form and the gradient of privacy in houses and housing
- Learning the potential of commonly used spaces
- Learning how to design common spaces
- Learning about how to design housing for everyone (children, elderly and differently abled people).
- Learning about the behavior of architecture in relation to weather and climate
- Learning about the behavior of materials
- Learning about the behavior of structure and gravity
- Learning the basics of detailing and construction

Skills:
- Hand drawing by pencil
- CAD drawing and 3d modeling
- Model building
- Learning the character of different tools, the skills to apply them as design methods and hybridizing them to achieve the desired results.
Architectural behaviorology and actor network theory are our two guiding principles to not only design architecture but also understand our current existing environment. By understanding a building, a house not as an isolated object but as a node in a vast and far reaching network, or several networks, we grow conscious of the impact, which our design has, not only on the specific plot, but on the neighbors, the city, the environment, the society. Vice-versa, analyzing and understanding the networks, which have shaped existing buildings, helps us to better understand how and why the design of those buildings came to be. While identifying the relationship between actors within the network, we simultaneously observe the behavior of each actor as a result of their relationship. The behavior can be static or dynamic, actors can be human, non-human, animate or inanimate. How does a building behave towards its environment? What behavior do inhabitants engage in within and around a building? How do we have to design to take Behaviors of certain materials into account? House and housing is the base of our living environment and a diverse fields in architecture. House behaviorology will set the challenge to find sustainable living condition in the city, by understanding historical examples and their geography, density, economic standing, and time period. At first, to find the character and essence of today’s house and housing design in Zurich, we will start with analyzing existing single-family houses in and around the city. We will research and map how these basic units of housing relate to the users, to each other and to their surroundings. What kind of purposes they fulfilled and what kind of activities and behaviors do these houses enable? Second, we will try to improve on the design by changing the single-family house into housing complexes, responding to the need of greater density, but still retaining the qualities of the original houses. Where do we find synergies, when combining houses? What kind of common spaces arise and how can we make use of them to make better neighborhoods? Simultaneously we will have a close look on designing for inclusivity. How do we design for marginalized groups, such as the elderly, children or differently abled people? How can we live together in the urban ecology?

Grading Criteria
The submissions will be graded before each review. Students are expected to do individual work. Each submission will be graded according to the following points:
• Completeness and punctuality of the submission
• Research method, the ability to find and analyze information
• Understanding of the concept of behaviorology and the ability to implement behaviorology within the design
• Structural design, construction details and choice of material, in connection with concept of behaviorology and the actor network
• Choice of typology and design, in connection with the concept of behaviorology and the actor network
• Visualization, the ability to make easy to understand and compelling drawings
The final grade consists of the following partial grades:
• Mid review 1 submission: 30%
• Mid review 2 submission: 30%
• Final review submission: 40%

Lecture notes
Each student will receive a printed reader, containing the basic information about the course, such as schedule, syllabus and other important information, as well as examples and references for the design task, and readings to support the theoretical framework of the course.

Prerequisites / notice
To attend this course, students have to enroll through the "Enrolment in the Design Studios of D-Arch"-page: (www.einschreibung.arch.ethz.ch/).

The design studio is structured as a year-long course. The submissions during the autumn semester will be individual work. Schedule Autumn Semester 2021:
• Introduction 21.09.21
• Mid Review 1: 12. & 13.10.21
• Mid Review 2: 16. & 17.11.21
• Final Review: 21. & 22.12.21
Individual work only.
Costs: ca. 100 CHF (besides the seminar week)

Assistants
Teaching: Sandrine Badox, Tanguy Caversaccio, Christoph Danuser, Kelly Man
Research: Tazuru Harada

Collaboration: GTA, Chair for the Theory of Architecture
ITA, Chair of Structural Design

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | assessed |
| Domain C - Social Competencies | Analytical Competencies | assessed |
| | Decision-making | assessed |
| | Media and Digital Technologies | assessed |
| | Problem-solving | assessed |
| | Project Management | not assessed |
| | Communication | assessed |
| | Cooperation and Teamwork | not assessed |
| | Customer Orientation | not assessed |
| | Leadership and Responsibility | not assessed |
| | Self-presentation and Social Influence | not assessed |
| | Sensitivity to Diversity | assessed |
| | Negotiation | not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |
| | Self-direction and Self-management | assessed |

052-0545-21L Architectural Design III: A Forest Bath (A.Spiro)
Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

W 14 credits 2V+14U A. Spiro, J. De Vylder, D. Mettler, D. Studer

Over the course of the design studio, you are going to acquire specific knowledge about different concepts of construction and apply them to your own projects. Central topic during the semester is the development of a design based on a central structural idea.

You will be working on
- a precise relation between spatial and supporting structure
- a materialisation based on the principles of the structural concept
- a concept for openings and lighting based on the principles of the structural concept

You will learn to develop your project based on
- your structural concept
- specific aspects of building in the forest
- your in-depth analysis of the immediate surroundings of the chosen site

Most of the spaces we design will not be insulated. This allows for a simple and direct way of construction. Based on this, you will work out a part of your project in detail, relating to measurements of the human body.

Concerning the representation of your project, you will
- learn a solid way of drawing in CAD in a 1:200 scale
- use combinations of CAD and analog drawing to convey the intended atmosphere
- use and enhance your hand drawing for 3D illustrations

By building physical models, you can
- learn about the adequate detailing in a respective scale
- simulate actual joinings and find out about their impact on the architectural expression
- develop further abilities to represent materials and surfaces in an appropriate way

The acquired knowledge in relation to structure, material, lighting, drawing and model building will be the base for the 4th semester where we are going to elaborate on these topics in a more complex way, designing urban residential buildings.

In this regard, our design task will be a forest bath in the Käferberg area close to the campus. Bathing in the forest allows a new experience of the local recreation area and adds a new level of use. The bath is explicitly not expected to feature a single large pool. Hence the actual way of bathing in the forest needs to be developed specifically in every project based on the structural idea and specific aspects of the chosen site. The bath is supposed to be open all year round. Therefore it offers both open and enclosed spaces, a rest area and the usual auxiliary spaces of a public bath. Special attention will be given to the transition of indoor and outdoor spaces which offers vast opportunities for specific designs between covered and uncovered, bright and dark, open and closed, and intelligent concepts for heated and uninsulated spaces.

During the definition of our approach to the design task, we will have several opportunities to spend time in the forest and get to know the controlled natural environment of the “urban forest”. In several exercises at the beginning of the semester, we are developing collections of objects, drawings, and impressions. This pool of ideas will be present in the studio as a base to define your own field of interest, which will later condense in your projects.

The forest will be present in the studio in the form of a large model which we are going to build during the first weeks as a base for your daily work on your projects and the critiques. During the course of the semester, you can choose from a range of sites that differ in respect to the density of the forest, topography and access.

Throughout the 3rd semester, we are focusing on structure as a catalyst for our designs. You will learn about different structural concepts and apply their basic principles in your projects. Further key aspects are the use of materials and their inherent properties, a conscious way of designing with daylight, and the development of coherent roof structures.

Outlook 4th Semester

Next semester, the core subject of our studio will be programme instead of structure. We are going to design residential buildings in Zurich. Starting from a selection of inspirational houses and apartments which we are analysing and measuring during extensive visits at the beginning of the semester to get an understanding for their architectural elements and spatial, you are going to develop your own specific form of living. From a selection of different sites in the city center, you determine the best suited for your project and develop dwellings right down to the materialisation in detail. In doing so, we will pick up and elaborate the topics we are touching in the first semester on a more complex level.

The 3rd semester has been newly developed based on core topics of the chair. It replaces the respective fall semester courses which used to focus on working in the built fabric. Further information about the housing semester are available on our Website in the form of semester documentation brochures (see Small Pleasures of Life I-III, https://spiro.arch.ethz.ch/lehre/zweiter-jahreskurs).

For the 4th semester, we are going to elaborate on these topics in a more complex way, designing urban residential buildings.

Students who do not wish to change the design class don't have to participate in the internal enrolment.

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is also the ultimate deadline to unsubscribe or enroll for the studio.

Abstract

We are going to design a bath in the nearby forest. You are going to acquire profound knowledge about structural concepts and work with contradictions and corresponding aspects between spatial structure and support structure. Further key aspects are materials and their inherent properties, light and the roof structure as such. The specific context of the forest strongly informs the design process.

Objective

Over the course of the design studio, you are going to acquire specific knowledge about different concepts of construction and apply them to your own projects. Central topic during the semester is the development of a design based on a central structural idea.

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- a precise relation between spatial and supporting structure
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Lecture notes

Documents provided by the chair.

Literature

We will be reading and discussing texts that are relevant for the main topic of the current series of exercises on a regular basis (extracts provided by the chair) throughout the semester.

Book recommendation BUK I - IV: “Construction”;
A reference work on contemporary construction
German or English
360 pages, 171 images, 20 color images, texts
ISBN 978-3-0356-2225-6
Online reference source: https://www.hochparterre-buecher.ch/ Konstruktionen.html

Autumn Semester 2021
Abstract
In semester HS / III, a simple exercise will explore the development of the same program in the two different contexts of NEW-USE and RE-USE. On a given free plot versus a given build plot, the same project will be designed. In the FS / IV semester, the same simple exercise will test the results of the previous semester on a subsequent change.

Objective
It is clear. As good as the whole realm is on track on Re-Word today, a critical moment must be ambitioned. But not just to be critical. But to give the idea of Re-Prefix a chance to go beyond the tendency and give a chance for a truly different Future of Attitude. Not just a Pragmatic Future, but a Future to Dream about. d-RE-AM. About.

Content
The 333% studio is a studio on the scale of the BA SEM III & IV expectations. At the same time, the 333% studio is part of a broader ambition shaped by the title 3.33% 33.3% 333%. In fact, these 3 sets of 3 numbers are 3 different studios but sharing the same interest 3 times. The interest of RE-USE. In the 33.3% and 3.33% studio - MA SEM I, II and III - the idea of economy, ecology and ergonomics is explored with a gesture of 3.33% or 33.3% of the normal 100% investment. A true belief in the under-explored capacity to really do less. Or said: needing less.

The 333% studio takes the perspective across two semesters - HS / III and FS / IV. In semester HS / III, a simple exercise will explore the development of the same program in the two different contexts of NEW-USE and RE-USE. On a given free plot versus a given build plot, the same project will be designed. In the FS / IV semester, the same simple exercise will test the results of the previous semester on a subsequent change. Both projects from the previous semester will be challenged with a new program, twice each time. One can say: it is a matter of RE-USE - semester FS / IV - of the RE-USE and the NEW-USE - semester HS / III -.

We introduce the word (P)RE-USE here since the NEW USE - semester HS / III - will still be tested in its first concept for its ability to be prepared for the next RE-USE. Likewise, the RE-USE project will be evaluated for its ability to change once more.

We will talk about many more RE-PREFIX words. The RE-WORD - once started with the word RE-USE - is everywhere and always today. The RE-word is omnipresent and in many ways. Many RE-words have now been found and defined. And many more must and will be added. Never is it a play on words. Always it is another angle. Or to explore the idea more and more. And to discover yet another entrance.

At all. We will find out together that in the end, taking into account all these RE-WORDS, it is and will be more a matter of RE-ATTITUDE. USE words in account. Attitudes must be changed. At all.

RE-THINKING-RE is the alter ego of the 3.33% 33.3% 333% studios. If we are not critical, RE-ERA may only be a trend, but in fact it is and will always be an eternal URGE. The urge of u-R-g-E.

It is clear. As good as the whole realm is on track on RE-WORD today, a CRITICAL moment must be ambitioned. But not just to be CRITICAL. But to give the idea of RE-PREFIX a chance to go beyond the tendency and give a chance for a truly different FUTURE of ATTITUDE. And not just a PRAGMATIC FUTURE, but a FUTURE to DREAM about. d-RE-AM. About.
In HS21 in Falera, we will investigate the question of whether, in our time of individual action and unrestricted access to materials, places...

Program: caminada.arch.ethz.ch
Architectural Design V-IX: Small Institutions (GD)
14 credits
assessed
16U
assessed

Architectural Design V-IX: Falera Village - Attempts after the Community of Fate (A. Caminada)

Abstract
In HS21 in Falera, we will investigate the question of whether, in our time of individual action and unrestricted access to materials, places can emerge that are able to inspire us.

Objective
In teaching, we remain true to our goals and do not want to teach students a certain type of architecture - be it in terms of methods, images or styles. Rather, what needs to be developed is an idea that supports the location. The idea must be a spatial equivalent of the design. In the course of the semester, the focus is on the material and construction used, and also on the spatial atmosphere that can support a certain event. In the end, the idea, shape, construction, material and atmosphere should be in a coherent relationship.

Content
There are places that touch us. The conditions that led to it were very different. In the mountain regions, for example, foreign capital worked on important trade routes or at the base of pass crossings, in other places the power of faith and religion. In remote regions, living conditions were very modest. Due to the limited availability of materials, people had to be inventive. The possibilities for action were not limitless. It was necessary to observe the regularities written in the materials. The power of a place and its architecture emerged from the repetition of the almost identical.

Many mountain villages were in a similar situation. There were major changes towards the end of the last century. Above all, tourism and the hotel industry, followed a little later by the construction of second homes, led to modest prosperity. The new opportunities resulted in a radical decline in agricultural livelihoods. The social structure of the village and the influence of the church have fallen. Liberation from these mighty bonds has been a relief for many. Effects were not lacking. Individual forms of life and the disappearance of local knowledge led to a leveling of phenomena in the entire Alpine region. The power of a specific place has largely been dissolved.

The freedom gained also has a downside. The canon of values that characterized the culture of space has disappeared. Orientation guidelines are always in question.

The big change also took place in the Graubünden village of Falera. The small farming village became a tourist place. Falera still likes to see itself as a farming village. Agriculture is still present. With the change, the farmers have moved to the edge of the village. The stables in the village center are empty or have been converted. Holiday homes were built in the style of farmhouses. The stable entity, which used to see itself as a farming village. Agriculture is still present. With the change, the farmers have moved to the edge of the village. The stables in the village center are empty or have been converted. Holiday homes were built in the style of farmhouses. The stable entity, which used to...
Managing with environmental conditions of a site (orientation, visual, circulation, resources, pre-existences, etc.).
- Having the ability to rethink the pre-established and the interest to discover unknown approaches.
- Incorporating an emotional approach to architecture – designing from experience.
- Controlling and articulating the various qualities of space (dimensional, material, environmental, etc.).
- Integrating the behaviour of the building as a fundamental part of the project.
- Designing with natural systems and thermodynamics to create spaces with “real” comfort.
- Re-learning how to live and build in future climate paradigms.
- Knowing how to find expression and character of spaces through the use of matter.
- Understanding the potential offered by construction systems and technology.
- Combining technical decisions with formal ones in a significant way.
- Detecting opportunities to give innovative answers to the relationship between buildings and nature.
- Incorporating interdependence as a determining factor in the design of buildings.
- Organizing the work in a way, which is appropriate to the available time and the requested objectives.

Objective

Content

Amplitude. Dynamic landscape structures for the Zealand.

Architectural Design V-IX: (N.N.)

Architectural Design V-IX: Amplitude (Guestprof. M. Voser)

Prerequisites / notice

Individual work and group work, whereof at least 5 weeks of group work.

Critiques: Dates will follow.

No extra costs.

052-1105-21L Architectural Design V-IX: (N.N.)

Does not take place this semester. Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract

Not offered in HS21.

052-1107-21L Architectural Design V-IX: Amplitude (Guestprof. M. Voser)

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract

Amplitude. Dynamic landscape structures for the Zealand.

The search for future-oriented strategies in dealing with these extremes requires a paradigm shift - from fighting against to working with natural processes. It is necessary to lay new landscape structures that can deal with the fluctuations of the amplitudes.

Objective

Basic knowledge in landscape architecture, development of an attitude, formulation of a hypothesis, choice of appropriate design elements, design and representation of complex / dynamic systems and landscapes, alternation between different scales.
Heat, drought, heavy rain events - in the course of climate change, the extremes are getting stronger and the frequencies in which they occur faster and faster. Natural and cultural landscapes that were in equilibrium until a few years ago need to be adapted. These changes will not only affect the life of flora, fauna and people, but also the character and ultimately the identity of our Swiss landscape.

The search for future-oriented strategies in dealing with these extremes requires a paradigm shift - from fighting against to working with natural processes. It is necessary to lay new landscape structures that can deal with the fluctuations of the amplitudes.

But how can the forces of extremes be used and turned into positive things? And how should the new landscape deal with the dynamics - direct, balance, absorb?

As the most important production area in Switzerland, the Three Lakes Region is exposed to these extremes, as witnessed by the debris flow in Cressier and the floods in July as well as the dry periods of recent years. Therefore, the third Jura water correction is currently being considered, which, in addition to the previous tasks of large-scale drainage and bed load management, also includes irrigation.

The territory between Lake Neuchâtel and Lake Biel is characterized by the most varied levels of culture, infrastructure, settlement and industrial landscapes. The spatial planning consideration reveals extremes: small-grained, historical settlement cores collide with sprawling industrial areas such as the last refinery in Switzerland.

In search of new scenic identities for this valley, we will deal intensively with systems, processes and strategies without losing sight of spatial qualities, atmospheres and poetry.

The introduction of a new water system serves as a design engine. Due to the complexity of the territory and the task, an iterative design method is pursued that oscillates between design and analysis and between large and small scales. The development of an attitude, the crystallization of the specific topics and the selection of the appropriate design means are just as much a part of the work process as the design of the transformation processes.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>Group work only.</td>
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<tr>
<td>Critiques: 13.10.21, 17.11.21, 7.12.21.</td>
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<tr>
<td>Costs: CHF 150.-- (besides seminar week).</td>
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</tbody>
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### 052-1109-21L Architectural Design V-IX: Meteora 05 - Engenderings

<table>
<thead>
<tr>
<th>Architectural Design V-IX: Meteora 05 - Engenderings (L. Hovestadt)</th>
<th>W</th>
<th>14 credits</th>
<th>16U</th>
<th>L. Hovestadt</th>
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</table>

*Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).*

*Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enrol for the studio.*

### Abstract

This studio works on the idea that a substantial understanding of today's technology (internet of things, big data, machine intelligence ...) changes the perspective to architectural theory and will result in different architectural designs and building constructions.

### Objective

1) Identification and understanding of the challenges of today's technologies;
2) techniques of working within the plenty of the internet;
3) a methodology to design digital architectures;
4) understanding of the shift from hard building construction to soft building applications, and
5) an understanding of the importance of becoming a literate digital persona in order to be an architect today.

### Content

**METEORA #05 ENGENDERINGS**

**FASHION, JOURNALISM, FEMINISM**

*‘IF NATURE IS UNJUST, CHANGE NATURE.’*

**About freedom, nature, technology, gender, intellect.**

**What it is, a HUMAN?**

**Gendered by nature or engendered by ratio?**

**An architectonic stageplay:**

Coco Chanel (1918) moves into the Villa Lemoine of Rem Koolhaas (1998) to discuss the XENOFEMINIST MANIFESTO (2018)

**METEORA #05 will use artificial intelligence**

*to write a text to explicate a precise position in today’s world,*

*to create a spectrum of images to reflect this world* and

*design an architectural artefact which brings things into adequate proportions*
Visibility and its Hidden Dimensions:

If something catches the eye, what is next to it will be mechanically less looked at. For a light to appear, it has to emerge from the surrounding darkness. And what attracts the light often leaves its surroundings in shadow. Hence an implacable theorem: the visible is always born from the invisible.

Visibility and movement:

There are also territories where one does not stop, places devoted to transit and exchange (business and industrial zones, areas near railway stations or airports, etc.). From these places, we can only have a partial vision, but also a vision in movement, a dynamic vision. From then on, they call for an architecture that adapts itself to this new speed of vision, and which opens onto another imaginary world. The history of art is full of these regenerations: the impressionists who revealed a new Paris by painting the "hidden banks" of the capital on the outsides of the stations; street-art which gives back a cyma value to the gable walls, elements a priori the least worthy of attention in architecture.

Visibility and intimacy:

There is a "hidden dimension" (to use the title of Edward T. Hall's famous essay) that concerns our bubbles of intimacy, which vary according to times and cultures. These spheres remain the founding gauge of the human relationship with architecture. At what distance is a vis-à-vis acceptable? At what point does one start to see too much? Where is the boundary between proximity and voyeurism? Here we think a balance, both intimate and social, between the visible and the invisible. What's more, we are living at a time when the apprehension of these "bubbles" is being altered by the health crisis.

Visibility and illusion:

The gaze is, in any case, fallible and to take note of it is also to explore new areas of the visible. The art of trompe l'oeil works on certain productive ironies between painting and architecture (the frescoes in the Hall of Giants in the Té Palace in Mantua, a simulacrum of a building collapse, or closer to us, the "masking" of the Louvre Pyramid by J.R.). This art of camouflage does not always have artistic aims. Just think of the tarpaulins that hide the scaffolding on monuments that are being renovated, and on which the façade of the monument in question is drawn or photographed. Proof of the need to keep the facade of an emblematic building in the field of visibility (and even in the simulacrum mode)!

Visibility and new tools:

The change in the way we look at things is also accompanied by an addiction to new tools. The advent of the digital image has had an unexpected consequence: in the cinema, in photography, on television, the nights are "dimmed the light" of the day, not that day and night are two opposing reigns. And what attracts the light often leaves its surroundings in shadow. Hence an implacable theorem: the visible is endowed with an enveloping dimension, with the impression that one can get lost in it. A digital night simply makes you believe that you have "dimmed the light" of the day, not that day and night are two opposing reigns.

Objectives:
- Critical thinking, personal attitude:
  - Demonstrate, through design work, a critical understanding of climate change and the ethical responsibilities of the architect
  - Reflect on pieces of work in progress or already completed both individually and in conversation with peers and faculty
  - Demonstrate, through design work, a growing knowledge of contemporary and historical architectural discourse
  - Critically interpret requirements and working priorities in light of constraints to work practice arising from Covid, home working and personal circumstance. Communicate with teaching team if difficulties arise.

Working methodology:
- Conduct qualitative site/building analysis through photography and observational drawing
- Perform basic topographic surveying
- Use archives to conduct systematic analysis into social history, uses, materials, etc.
- Interpret and synthesize information into a concise and ongoing knowledge base for the design of a project
- Develop an understanding of the geology, climate, ecology, etc. of a place
- Assimilate small, fragmentary observations into broad understanding of place

Acquisition of subject-specific knowledge:
- Consider and understand the relationship and impact of a design on a wider landscape
- Understand the impacts of construction on ecology
- Demonstrate an understanding of the impacts of time on the repair and maintenance of a project
- Demonstrate an understanding of contemporary and historical construction techniques
- Demonstrate a critical understanding of the use of materials in relation to non-renewable resources, embodied energy, recyclability

Conversion of a conceptual intention into an architectural project:
- Develop an integrated and relevant structural, constructional and environmental concept for the project
- Formulate a spatial concept for a project, demonstrating an understanding of conceptual, spatial and programmatic decisions
- Design with reference to historical, political, cultural and other creative and technical fields
- Demonstrate an ability to assimilate a broad range of working practices, identifying and engaging especially with those which help to demonstrate and further ideas

Capability to design:
- Demonstrate an ability to design interior and exterior spaces, as well as the thresholds and the surrounding spaces
- Demonstrate awareness of a design project’s environmental performance in construction and in use
- Demonstrate a good understanding of professional regulation and ethical responsibilities of the architect
- Design buildings, spaces and landscapes which are fully accessible

Representation and presentation in different media:
- Develop a critical eye in photography of place, space and design work with reference to broad photographic traditions
- Develop model making skills of small conceptual models, as well as working models made of everyday household materials, with precise conceptual purpose
- Demonstrate high technical and critical proficiency in 2D and 3D CAD drafting and modelling
- Develop an understanding of the status and purpose of different kinds of representation, and deploy them effectively
- Use detailed drawings and models to illustrate the conceptual construction of a project
- Demonstrate high technical and critical proficiency in image making and collage
- Clearly and concisely describe a concept, working practice, and outcome through written and oral material in English or German.
- Explore use of film and short film clips to present three-dimensional work. Note, advanced editing skills is not required.

Engagement in the studio:
- Actively participate in group projects such as the garden
- Actively listen to others
- Be able to learn alone, as part of a group and as a whole studio
- Demonstrate an ability to work comfortably with ambiguity as circumstances change
- At all times demonstrate honesty, integrity and respect for fellow students, teachers and staff.

Content:

- The architecture of the city lies between the buildings. Too complex in nature, form and design to be understood as a single space, ground has become the network of mobility that defines the contemporary city. This semester, earth works will be the primer for a new experimental garden prepared with the Crowther Lab which, in turn, lead to actions across Zurich’s greatest continuous interior.

- At all times demonstrate honesty, integrity and respect for fellow students, teachers and staff.

Prerequisites / notice:

- Individual work and group work, whereof at least 5 weeks of group work.

Critiques: Dates to follow.

No extra costs.
We are continuing to explore the theme of cohabitation: the interplay of human and nonhuman systems in our built environment. We are focusing on a given ecosystem, as the context for our architectural proposals. Further, we are expanding our toolbox: storytelling and film continue to play an overarching role, but we are opening up the studio to other media and forms of architectural exploration.
The design studio is aimed at the students acquiring the following skills:

**Objective**

- Prefigurative Architecting
- The ability to think in different scales and systems, in order to determine issues and themes by observing the changing conditions of our environment. The aim is to develop an architectural position in relation to these observations and to translate it into a viable and sustainable proposal for the future of our coexistence.
- Storytelling and Narrative-Design
- The ability to translate factual knowledge about architecture and architectural systems into a story. These narratives function in parallel and offer other ways and speeds of communicating the design arguments besides the factual approach. In addition to time-based media such as film and episodic video formats which we call television, we will be developing additional formats with the students from this semester on.

Both learning objectives will be introduced in topic-specific lectures at the beginning of the course.

**Content**

This semester we are continuing to explore the theme of cohabitation: the interplay of human and nonhuman systems in our built environment. But this time, we are focusing on a given ecosystem, as the context for our architectural proposals. Further, we are expanding our toolbox: storytelling and film continue to play an overarching role, but we are opening up the studio to other media and forms of architectural exploration. (see learning objectives)

“Europe's sea of plastic”, Almería in the south of Spain, is our point of departure. It is one of the many places where our globalized and accelerated ways of life become visible and take on built form. Together, we want to explore and understand the different types of architecture that can be found on site. Dating from different times, created for different needs. A deeper understanding of the systemic relations of these local structures is essential in order to become active and to produce architectural models for the future — for Almería and beyond.

**Global (Eco)Systems**

The ongoing industrialization and urbanization of our environment is the main driver of depletion on our planet. These changes are human-made, which is why we speak today of the Anthropocene: an unofficial unit of geologic time, used to describe the most recent period in Earth’s history when human activity started to have a significant impact on the planet’s climate and ecosystems.[1]

It is indispensable taking a look at the motives and conditions of our global actions, which laid ground for the occurrences and changes we are experiencing today and which led to the concept of the Anthropocene. Exponential growth has long been the western societal leitmotif, which places economic interests over ecological ones. But as economist Kenneth Boulding puts it: Anyone who thinks that you can have infinite growth in a finite environment is either a madman or an economist.

And although Western societies have access to data and knowledge about the consequences of their actions, and the limits and finiteness of the Earth’s ecosystem, we still seem unable or unwilling to act differently. The concept of the Anthropocene sees humanity equally responsible for this change. But it was mainly Western societies that emitted and benefited from the massive industrialization and are triggering the ongoing urbanization of our environment. From a relative point of view, it was the capital that drove Western societies. This is why other scholars such as environmental historian and political economist Jason W. Moore have been prompted to recast the notion of the Anthropocene, with the more nuanced and connective concept of the Capitalocene.

Capital-driven thinking is also evident in architecture, both in the built and unbuilt environment. Every crisis, including the most recent one, has caused economic eruptions that led to increasing investments in land and real estate and thus, resulted in profit-oriented-architectures. These take shape in different places, forms and typologies. Exploring them is of great importance, in order to understand the local and global role architecture plays in different systems. By doing so, we reflect on how urbanization — as the most prevalent socio-material form of environment-making under capitalism — has re-ordered human and non-human relations in profound ways.[2] This knowledge enables us to design an architecture that questions the status quo and, beyond that, creates new spaces for our coexistence.

- Individual work and group work, whereof at least 3-4 weeks group work.
- Critiques: 19.-20.10. and 23.-24.11.
- Costs: CHF 100.-- (besides seminar week).
- Prerequisites / notice
  - Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).
  - Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.
- **Objective**
  - Understanding and exploring your body and the senses to design and facilitate dialogues.
  - Developing your ability to improvise and adjust to a dynamic environment.
  - Collaborating with a multitude of actors from different (professional) backgrounds.
  - Identifying physical and intangible borders and boundaries that define space.
  - Communicating complex ideas through a performative approach to architecture.
  - Being a host and creating a welcoming environment for a wide variety of people.
  - Documenting a non-linear creative process through a mix of media.
  - Getting immersed in the world around you.

- **Grading criteria:**
  - Clarity and Independence of Position
  - Relevance regarding the case
  - Depth of engagement
  - Representation
  - Design in Dialogue
  - Mutual Collaboration
  - Personal Development
Content

After a long period of forced social distancing and self-isolation, we will be seeing each other soon for the start of the semester. Finally freed from endless Zoom sessions, we can reconnect to the people and places around us. Our HS2021 design studio centres around this reconnection and rediscovery of the physical world and the power of proximity and embodied knowledge. Starting from ONA, the building where we are developing the Design in Dialogue Lab, we will use our brains, bodies and all of our senses and creativity to explore the building’s potential as a safe and social space where we can be and work together.

Like many other buildings in cities across the world, ONA was not built to foster human life and interaction. As a welding factory, it was meant for machines. Situated on the border between Oerlikon and Seebach, it was part of an industrial zone where a.o. weapons were produced. In recent decades the area was transformed into a primarily residential neighbourhood, and the ONA building was converted into a mixed-use office building with ETH being one of the main tenants.

While approaching or entering the ONA building, you are confronted with a series of both physical and intangible obstacles and borders. Despite efforts to make it more accessible, the building’s introverted nature continues to echo in its appearance. The grey concrete walls communicate the story of a space constructed to keep noise inside and people outside. Surrounded by railway tracks and other infrastructure, the main entrance is hidden behind a busy loading bay where trucks pull up during the day to load or unload goods. Once inside, the vast open ground floor is subdivided by walls in an attempt to create a sense of intimacy.

By joining Studio Seebach - Sensing Space, you will become part of a collective effort to identify, reimagine, and potentially remove or redesign some of these barriers. As users and hosts of the space, we will revisit ONA and explore it as - what we like to call - an 'Open Public Structure' that is welcoming to a wide variety of users, from students to local residents. Simultaneously we will also question whether ONA should become a seamless environment or keep certain ‘meaningful thresholds’ that help preserve existing values.

Instead of taking an intellectual approach based on a rational analysis of the spatial conditions, we instead will introduce a more intuitive approach that makes use of our senses and explores our body’s ability to experience the (open) borders and (closed) boundaries that define ONA. We will be joined by practitioners from such diverse disciplines as dance, performing arts, anthropology, philosophy and club culture who will help us to Swarm, Sense and Settle.

French philosopher Maurice Merleau-Ponty once wrote that: “Rather than a mind and a body, a (wo)man is (...) a being who can only get to the truth of things because its body is, as it were, embedded in those things,” According to him, we are all “caught in the fabric of the world”. His words resonate with the assignment formulated by the late American composer and philosopher Pauline Oliveros (“listen to everything until it all belongs together and you are part of it”). The studio takes inspiration from these and other thinkers and practitioners and turns their ideas into actions that allow you to test and train your senses and get immersed in the world around you.

Individual work and group work, whereof at least 3-4 weeks of group work.

Critiques: 19./20.10., 23./24.11.

No extra costs.

052-1123-21L Architectural Design V-IIX: Circular. From Material to W 14 credits 16U R. Boltshauser

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php.

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract

We as a society, but also specifically we as architects, must use land, resources and energy as sparingly as possible in the future. Therefore, the focus of the design is a holistic consideration of climate-conscious building: we are developing hybrid systems made of earth in combination with re-use building components.

Objective

- Dealing with dense, sustainable, simple building
- Development of a broad theoretical and historical knowledge of a topic in order to transfer the resulting findings to the current context
- Understanding of sustainable building techniques and building materials, rammed earth
- Holistic design of spatial atmospheres in the interplay of context, construction, climate, sustainability, and materiality
- Recognizing the potential of building materials with different technical properties in order to develop own ideas for new building systems and translate them into a design
- Practical work on the model and in the visualization program as part of the design process

Content

The Binz - an urban fragment, which with its contrasts and heterogeneous development forms an ideal area of investigation, is to be analyzed in the coming semester. The possibilities of a spatial redensification of the entire area will be examined and a vision for the future in the form of a master plan will be developed. In addition to the large-scale studies, the focus will be placed on the material clay, as a low Co2 building material, right at the beginning of the semester. Inspired by the history of the Binz region as a clay mining area, clay samples taken on site will provide information on the composition and processing potential of the material. Not only the local availability of clay, but also the positive physical properties of the building and the low proportion of gray energy speak for an examination of this material. Based on the findings of the clay samples and the knowledge about synergies and compensation potentials with other materials such as wood or recycled materials, prefabricatable hybrid nodes will be developed at the beginning of the semester, which will be realized as mock-ups during the seminar trip. The development of the nodes thus becomes the primary design element. In addition to material technology and construction issues, we will pursue a climate-based design methodology that sees the responsible use of finite resources and thus cycle-based construction and the reuse of building materials as the potential of a new, contemporary architectural expression.

A new awareness and thinking in dealing with finite resources will also let us this semester explore the material clay for its various properties. In addition to the low proportion of gray energy and the outstanding physical properties of the building material, the local availability of the material is of interest. Millions of tons of clay-containing excavated material are produced worldwide every year, for which our construction industry has no use and which therefore has to be disposed of (over 25 million tons in Switzerland alone). So why not use this unused resource to build with?

From our point of view, however, this requires new building methods that correspond to today’s standards and needs for a rational construction method and that better exploit the physical potential of the building material. Prefabrication, a hybrid clay building technique or liquid clay technology are examples of possible answers.

Lecture notes

The students will receive a reader at the beginning of the semester.
### Prerequisites / notice

- Participation in the seminar trip is recommended.
- Individual work only.
- Critiques: 12.10.21, 9.11.21, 30.11.21.
- Costs: CHF 35.-- (besides seminar week).

### Taught competencies

<table>
<thead>
<tr>
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<th>Type</th>
<th>Competencies</th>
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<td>A</td>
<td>Subject-specific</td>
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<td>Techniques and Technologies</td>
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<td>B</td>
<td>Method-specific</td>
<td>Analytical Competencies</td>
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<td></td>
<td></td>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
<td>assessed</td>
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<td>C</td>
<td>Social</td>
<td>Communication</td>
<td>assessed</td>
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<td></td>
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<td>Cooperation and Teamwork</td>
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<tr>
<td></td>
<td></td>
<td>Customer Orientation</td>
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<tr>
<td></td>
<td></td>
<td>Leadership and Responsibility</td>
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<td></td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>D</td>
<td>Personal</td>
<td>Adaptability and Flexibility</td>
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<td></td>
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<td>Creative Thinking</td>
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<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

### Architectural Design V-IX: Elemental Living (E. Mosayebi)

- **052-1125-21L**
- **W** 14 credits 16U E. Mosayebi

*Please register ([www.mystudies.ethz.ch](http://www.mystudies.ethz.ch)) only after the internal enrolment for the design classes (see [http://www.einschreibung.arch.ethz.ch/design.php](http://www.einschreibung.arch.ethz.ch/design.php)).*

*Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.*
Abstract
How do we want to live? Hardly any building task in architecture is so fundamentally and so strongly determined by conventions as housing. The focus of the work in the studio is the critical and experimental examination of new forms of living in different climatic regions of Switzerland.

Objective
- Knowledge of history, theory and typology of basic elements.
- Design of new forms of housing
- Pictorial representation of complex narratives in the form of miniatures
- Constructive Details
- Experimental photography

Content
How do we want to live? Hardly any building task in architecture is so fundamentally and so strongly determined by conventions as housing. The focus of the work in the studio is the critical and experimental examination of new forms of living in different climatic regions of Switzerland. The comparatively small scale allows the projects to focus on the themes of interior space, living form and basic architectural elements.

These basic elements are understood comprehensively and mean not only structural elements such as load-bearing parts, windows, doors, stairs, but also include secondary components such as beds, tables, curtains. Is it conceivable to develop the living form starting from an architectural element or furniture? Can we imagine a habitable elevator? How would a floor plan be designed starting from a refrigerator? Who would inhabit such spaces? The basic elements represent the thingness and craftsmanship of architecture. In the discourse on social and ecological building, the importance of everyday elements is often forgotten, even though it is the things themselves that create meaning or absurdity between life and the world.

Starting with a basic element, you will analyze at the beginning of the semester the specific characteristics and the variety of manifestations in different geographical contexts. You will ask: What functions does the element serve, what histories has it gone through, what norms has it cemented, in what materials and principles of construction is it created, and what future potential can it unlock? In addition to political, social, gender, and climatic contexts, you will also address the interaction of space, body, and scale, and thus the perception, impact, and use of architecture.

The semester takes place in cooperation with Prof. Dr. Ákos Moravánszky. In workshops with the artists Taiyo Onorato and Nico Krebs, experimental images of the projects will be created.

Prerequisites / notice
Group work only.

Critiques: 19.10., 17.11., 7.12.

No extra costs.

Architectural Design V-IX: (Girot) ▪

Abstract
Does not take place this semester.

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Literature
A reader will be provided at the introduction. Furthermore, a pre-selection of relevant books will be available to the students at the ILA Library.

Architectural Design V-IX: Structure and Space - Negotiation on the Inventory (GD Menn) ▪

Abstract
The theme of the studio is in the overriding interest for the architectural resource of the housing stock on the outskirts of Switzerland. We are concerned with the conversion of an industrial building that has been disused for decades in the rural context of the Gonzen mine in Sargans. Core topic is dealing with the phenomena of structure and space as a "negotiation" on and with this inventory.

Objective
The students learn to discover a building stock in its temporal and spatial structural context, which enables them to take a critical stance and to act as a designer. You learn to formulate an architectural idea of a change of use from the existing resource and to develop it into a consistent project.
The theme of the studio is in the overriding interest for the architectural resource of the housing stock on the outskirts of Switzerland. We are concerned with the conversion of an industrial building that has been disused for decades in the rural context of the Gonzen mine in Sargans. The core topic is dealing with the phenomena of structure and space as a “negotiation” on and with this inventory.

The subject is the Malerva ore processing plant, a solitary witness to the industrial history of disused mining in the Sarganser Rhine Valley plain. The iron on the Gonzen shaped the region for centuries. After numerous scientific and technical development steps, the extraction of raw materials attained its greatest importance during the Second World War, before the decline and the cessation of operations in 1966. The Malerva ore processing and sorting plant was designed in 1940 as a three-dimensional steel framework. Its structure and shape Free of aesthetic goals or thoughts of flexibility of use, it was tailored to the vertical and horizontal processes of ore processing and the economical use of the material.

Based on this special building typology and materiality, we would like to formulate design strategies for conversion and at the same time adopt an attitude towards the location and its historicity. We are researching the original machine, which today is a space structure that has lost its purpose. We are interested in the inner regularities and the thinking of the design from the conditions of the primary structure and material and the spatial potentials from them. We are guided by questions: What architectural relationship can be established with this filigree steel skeleton and its specific shape? Which spatial strategies and potentials does it open up? How evolutionary does an architectural concept emerge from the existing structure as a further development or how much does the intervention become a reshaping and new creation?

Programmatically, we design a mixed use in which a collective space formulates the heart of the facility. This public space is a new bearer of meaning and a meaningful part of the concept based on the existing conditions.

With the projects we would like to formulate answers to the memory and the future of this cultural heritage and to include questions of sustainability. In addition to dealing with material resources, we ask whether interventions in the specific space structure open up potential for a generic, open-use structure. Is a narrative conceivable that understands the project as an intermediate form in an open-ended life cycle?

Abstract

Building value. Extensive new developments continue to happen across Zurich and its periphery, with Ersatzneubauten still presented as the most desirable option. Even when a significant built substance exists, revenue-driven development patterns usually end up prescribing its demolition and replacement.

Objective

- Through inhabitation and close observation, identify material as well as immaterial strengths, weaknesses and potentials of existing buildings and neighbourhoods
- Understand and critically engage with the financial and social reality of urban developments
- Explore how to document and represent existing spatial conditions through different media
- Challenge the omnipresent practice of replacing existing buildings, through imagining their potential contribution to a more inclusive and exciting urban landscape
- Define a personal position about the agency of the architect and architecture
- Gain confidence in the design process with an ability to be critical and conscious, bringing all the aspects of the semester together in a personal and critical discourse

Content

Trust. A firm belief in the reliability, truth, or capacity of someone or something. A belief in the self, but also in the other. A state in which one might be seen as naïve and credulous, often leading to disappointments and failure, but that can equally be read as mature and looking for opportunities. Can one trust in something one does not yet fully understand? Can trust lead to following unexpected paths, not being afraid of encountering new ways of thinking and seeing?

Building value. Extensive new developments continue to happen across Zurich and its periphery, with Ersatzneubauten still presented as the most desirable option. Even when a significant built substance exists, revenue-driven development patterns usually end up prescribing its demolition and replacement. A gesture erasing existing users and uses at the same time, as those are rarely given a place in the planned developments. So how can we trust in the value of what is there? How can we learn from the existing to propose models for the future, a future capable of accommodating all the lives that can exist in the city, including the less profitable ones?

Regensdorf. This semester, after exploring Zurich and its surroundings twice by means of walking, we will inhabit a Dorf longing to be a Stadt. Next to the Regensdorf station, a real estate operation called ZWHAUT plans 1000 new housing units, developed by Pensimo and designed by offices including Peter Märkli, Roger Bolfshauser and Lütjens Padmanabhan. We will take a complementary and alternative look at the area. In collaboration with the diploma students reflecting on the new development, including its business plan and the types that it proposes, the studio will focus on an existing conglomerate of four buildings, investigating it as a potential candidate for re-use. Our discussions will focus on alternative typologies, architectural re-appropriation, economic models, and facade concepts. Together, those research tracks will take over the existing building, using it as a fertile ground for a polyphonic and grounded reflection on the future of Regensdorf.

Inhabitation. Your studio will be located on the empty fourth floor of an existing office building: 400 m2 at the very center of the future development. Moving in will allow us to engage with the day to day life of the buildings. It will make us complicit to what we design, to get close, and personal, to potentially find presences and qualities that are often overlooked and only surface in the slowness of being-in-it-together. This will allow us to become a critical audience reflecting on the decision making strategies behind large scale developments in the Zurich agglomeration. With our concrete and situated knowledge gained by actively being there, we will reflect on alternative futures for the four existing buildings, challenging the tabula rasa approach, and the accompanying architectural interventions and strategies.

The Dept. of the Ongoing. The Dept. of the Ongoing will move in with us to install an open research room, host the lecture series You’re Not My Type and surprise us with other ghostly modes of exchange and interaction.

Building Out Loud. During an integrated seminar week, we will take it a notch up and use our building as a test site, producing 1:1 interventions, guided by the skilled carpenters of NAME and the practice of scenographer Jozef Wouters and his Brussels based Decoratelier.
### Architectural Design V-IX: Change: Towards Hydroscopic Design (A. Holtrop)

**Objective**

In this design studio, you will define your gestures of making and working with material(s) through research and experiment, and in response to the topic of the studio. You are required to produce an architecture that results from your specific engagement with the material and the spatial condition you construct with it. The architecture that results from this approach does not reference or represent something, but simply attempts to exist as a physical spatial reality in its own right.

Your research should be supported by the knowledge made available by our studio, and engaged through you with the use of available resources and facilities at departments of the ETH and from external specialists.

**Abstract**

Architecture today is, to a large extent, about controlling water, whether in the atmosphere, in the soil, or in a building. Condensation, rainwater penetration and unwanted moisture can damage a building and impact on its longevity. An architect’s response to the durability of a construction and its materiality generally consists of designing resistance against weathering caused by water.

Our society increasingly demands controlled, standardised comfort: the building envelope separates indoor and outdoor climates and ecologies; the vapour barrier keeps window openings airtight and ensures the high performance of thermal insulation. In turn, the pesticide-applied plaster prevents mould growth on the façade.

When we take all aspects of the material into consideration – the geology, the sourcing, the industry, the different properties, the craftsmanship, the specialised techniques and the cultural significance – we can deploy the full potential of the inherent qualities of the material itself and your way of working it.

**Content**

This semester, we will focus on water. We will research water as an agency continuously shaping our environment and reacting to and forming other materials. At the same time, water will also be seen as the crucial element shaping the work of an architect.

### Architectural Design V-IX: Hortus (GD Deuber)

**Objective**

The students develop a design based on the architectural theme "Hortus" with the integrated disciplines of structural design. They deal with the topic, a specific material, its constructive logic and supporting structure. The aim is to arrive at a holistic design for all designs based on individual inspiration and the logic of the material and to visualize this at the end.

**Abstract**

The students have the opportunity to examine spaces that are shaped by architectural elements. We carry out this search throughout the semester and divide it into three phases: space, structure and whole. We will delve deeply into the architectural space and the materialized elements that define that space.

**Prerequisites / notice**

Individual work and group work, whereof at least 5 weeks of group work.

Critiques: 19.-20.10 / 23.-24.11;

Costs: CHF 250.-- (besides seminar week).

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**Table: Courses with Course Numbers and Credits**

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<td>Architectural Design V-IX: Hortus (GD Deuber)</td>
<td>14</td>
<td>16U</td>
<td>A. Deuber</td>
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**Notice**

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Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enrol for the studio.
The students have the opportunity to examine spaces that are shaped by architectural elements. We carry out this search throughout the semester and divide it into three phases: space, structure and whole. We will delve deeply into the architectural space and the materialized elements that define that space.

In a first step, elements that define the space are explored. Starting from an inspiration, rooms are designed that represent this inspiration. The rooms lead to a structure which, under the aspect of reuse, leads to its own detailed architectural project with an individual program.

The students work with working models, different types of renderings (renderings of the rooms and the structure), as well as detailed black and white CAD drawings and texts.

**Prerequisites / notice**

**Content**

They are often places along big roads, adjacent to infrastructural buildings, green spaces that do not have a clear function, or leftover spaces that are created by the parcelling and division of land. Precisely these spaces interest us this semester: the ‘unuseless spaces’.

Similarly, the landscape designer Gilles Clément writes about such spaces and their potential in his ‘Manifeste du Tiers paysage’ (2004). He calls these spaces the ‘third landscape’ and writes the following: ‘When one stops thinking of the landscape as the product of an industry, one suddenly discovers a multitude of undecided spaces without function for which it is difficult to find a name...they form a refuge for biodiversity that has been chased away everywhere else. Through their content, through the need to maintain this biodiversity or to keep its dynamics going, the third landscape takes on a political dimension. These spaces are frequently forgotten, overlooked and underdeveloped which is precisely what leaves room for freedom: freedom of experimentation for new ways of developing such spaces, emancipated from the constraints of the traditional market.

We want to think about these spaces which offer a potential for other creatures and plants: for biodiversity. In the first phase of the semester, we will study unuseless spaces in Zurich and approach them through the medium of film. At the same time, we will look at different architectural projects from history and analyse them through synthesis drawings as well as listen to presentations on possible potentials of unuseless spaces. In the second phase we will use the different analyses to develop projects that try to engage with the themes of these ‘unuseless’ land fragments, to create a habitat that is as diverse and varied as possible.

We will work with drawings, models and model photographs to illustrate the architectural and landscape ideas of the projects. We will also use synthesis drawings to summarise the different ideas of the projects. The work will take place in groups of two. The seminar week is integrated into the design studio.

**Objective**

The students should develop a narrative in the project, negotiate between different aspects of design resulting in a clear expression which synthesizes ideas into a coherent form.

**Abstract**

Artist Gordon Matta-Clark’s work ‘Reality Properties: Fake Estates’ (1973) shows a similar interest. In this work, he bought parcels of land that could not be built upon or used for real estate, formed when the land was subdivided into lots. These were narrow strips, some even narrower than a person’s shoulders, or inaccessible triangular remnants of land squeezed awkwardly between overbuilt lots. Matta-Clark was interested in these places which were worthless for the real estate market - land that had no value because it did not meet the demands of the market and was therefore technically useless.

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**Critical observations**

**Assignment**

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**Prerequisites / notice**

**Content**

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<td>052-1137-21L</td>
<td>Architectural Design V-IX: Story II - Unuseless Spaces</td>
<td>14</td>
<td>Fall 2021</td>
<td>M. Conen</td>
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Abstract
How can we as designers radically reimagine place-making in Sarajevo by connecting the existing natural and built environment with local resources and digital infrastructures as models for sustainable living?
The watershed of the Miljacka River has the potential to unlock socio-ecological systems and multifunctional corridors, that address urban fragmentation, and Climate Action.

Objective
Climate corridors Sarajevo. Shaping public water places.

Students will emerge in our Chair’s “method-design” to step by step develop their individual prototypical design projects. They will address both architectural urban scales and will be guided to collaboratively develop a baseline scenario. Mapping, identifying existing and future challenges and opportunities, students will take the role of stakeholders and translate their demands and resources into different scenarios. They will design urbanistic concepts and translate them into an evidence-based prototypical architectural project-intervention. This prototype is the synthesis of a process in time and space on different scales. The design project will be framed as a narrative that is consequentially visualized and communicated in analogue and digital graphic representations. The project concept will be tested and upscaled through urbanistic design-policies recommendations within overlapping spatial and programmatic systems of CLIMATE - CORRIDORS.

Content
The basic thesis for this Studio Fall Semester 2010 is constructing an urban imaginary creating an interplay of a linear public space system providing identity and orientation in the Miljacka River valley of Sarajevo. Sarajevo’s culture is as diverse as its rich architecture and history of urbanization. Located on the Balkan Route, a crossroads between north and south, east and west, the city confronts us with one of the highest pollution levels of air, soil water, of any capital city in Europe. The watersheds of the Miljacka River, wells, fountains, retention infrastructures, and flood plains are our point of departure. They have the potential to unlock socio-ecological systems, multifunctional corridors, and catalytic projects, that can transform fragmented neighborhoods, offering a living system of public water-places to the inhabitants.

At the intersection of architecture, landscape, and public art, the studio envisions trans-scalar processes and interventions, addressing the cities social and ecological crisis, in support of the Sarajevo Cantonal Planning Office, applying a systemic design methodology, and responding to the urgent need for concrete projects and Climate Action. Policy recommendations and general advice for upscaling such prototypical concepts are already successful in other cities globally and apply to the Sarajevo-Case.

The design challenge includes redesigning and densifying public open space, that combines social and environmental developments into a system of architecture, urban, and landscape design networks. The transformative re-development of existing street corridors and the interplay of architecture with landscape design and concrete prototypical and small-scale design interventions is critical for bringing together segregated communities in quality public space along degraded transport corridors. Linear multifunctional corridors can strategically connect to the immediate context and subcenters with feeder routes (considering Zmaja od Bosne), participatory public spaces, markets, playgrounds, production, and creating new eco-systemic connections with increased social and ecological qualities.

Atmospheric contamination, fine dust, and CO2 have created during inversion weather one of the highest air contamination levels of any capital city in Europe compromising the health of Sarajevo’s people. Climate change is challenging necessary processes to re-planting the forest and trees of the city. The compliance with the targets and indicators of the SDGs pose considerable additional tasks to solve. In recent years, the bust and boom cycle in Sarajevo has put doubt on opportunistic international urban upgrading models linked with opportunistic investments, gentrification, and short-term gains for private investors.

We have developed a toolbox by analyzing internationally recognized developments, sometimes permanent and temporary strategies such as Chengyecheon River Park, Seoul, Isapark, Schlaacht Hof / Munich, Corredores Verdes / Medellin or Cali, communal target-plan Zurich, Closed Highways in Sao Paulo or Bogota, Etc. These spatial processes have followed a widely known practice of consolidating a sequence of transformations, short-term strategies for long-term value production. Neighborhoods are re-evaluated through investment often initiated by art, popular culture, local participation, and place-branding.

Urban- and Landscape Design can create a measurable impact in cities by increasing social justice, health, and wellbeing. The development of robust frameworks adaptable to change enable processes for regeneration with long-term operational, environmental and social benefits in response to global, local, and site-specific challenges. The role of architects is to imagine and model sustainable urban scenarios recognizing urban corridors as new possibilities and lifelines to impact meaningful and multidimensional transformative design strategies.

Lecture notes
“Method-design”: Systematically engaging students in the Studio topic, to unlock their potential and skills towards developing prototypical design resolution on an urban and architectural scale. Identifying, understanding and developing local stakeholder networks, so as to translate challenges into opportunities and negotiate diverse interests into strategic ideas for development, geo-references, inter-linked systems, diagrams and maps. Develop design concepts for urban prototypes on different scales, framed by a narrative of a process that is consequentially visualized and communicated in analog as well as digital tools. Investigative Analysis/ Local Perspective: Registering the existing; prioritizing challenges and opportunities through qualitative and quantitative information; mapping on different design scales and periods of time; configuring stakeholder groups; connecting top-down and bottom-up initiatives; idea mapping and concept mapping; designing of citizen scenarios. “Project Design”: Synthesizing between different scenarios and definition of a thesis and program between beneficiaries and stakeholders; projecting process presentation as a narrative embedded in multiple steps; describing an urban and architectural typology and prototypes; defining an urban paradigm. “Domain Shift”: Shifting and translating different domains; testing and evaluating the design in feedback loops; including the project in the Urban Toolbox.

Literature
Reading material will be provided throughout the semester, as well as references to case studies. The class material can be downloaded from the student server.

### Prerequisites / notice

Team:
- Prof. Hubert Klumpner
- Anne Graupner
- Diogo Figueiredo

In collaboration with:
- UNSA | Faculty of Architecture, University of Sarajevo
- IPDS | Institute for Planning of Development Canton Sarajevo
- Prof. Adnan Pašić, Assoc. Prof. Dr. Aida Idrizbegović Zgonić, Prof. Dr. Gordana Mimisević, Prof. Dr. Pavle Krstić
- UTPS | Urban Transformation Project Sarajevo
- Dr. Michael Walczak, Bojana Papic, Victoria Soto Magán

Skills:
- Drawing & Representation | Michael Walczak and Melanie Fessel
- Introduction to Graphic Tools: Rhinoceros 3D, V-Ray, Grasshopper, Illustrator, Photoshop and InDesign.
- Graphic Design | Integral Designers, Ruedi and Vera Baur

Elective Course | ‘ACTION! Beautiful Data - The Filmic Art of Numbers’ is offered to complete the skillset of the studio, teaching in 3D modelling, filmmaking, and animating.

### Organization:

- Architectural Design V-IX | ECTS Credits - 14
- Integrated Discipline Planning | ECTS Credits – 3

Work: Group work during research / Individual project design

Language: German, English, Spanish and Portuguese

Location: ONA, E25

Participants: max. 18 students

All inquiries can be directed to Diogo Figueiredo: figueiredo@arch.ethz.ch

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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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### Architectural Design V-IX: Interim, Forever (A.Caruso)

| 052-1141-21L | 14 credits | 16U |

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract

Improvising and adapting have a long history in the built environment and now that the time for new building is coming to an end, perhaps architects need to more fully embrace the sensibility of the interim.

Objective

Qualification to control the design process increasingly independent and with sole responsibility and to find an individual design methodology and attitude.
Refining an idea until it is precise, developing a project so that it can be materialised, managing a design through the complexity of realisation. Architecture takes a long time and there is a strong temptation to reach for the eternal. Most of the constructed environment around us emerges out of even more complex circumstances and yet often comes together more quickly and flexibly. Are there things that architects can learn from how a farmer plans their fields to be productive and sustainable, how a tailor can mend a garment so that if it acquires qualities that didn't exist in the original, how resourceful builders can make do when materials and time are in short supply, improvising and adapting having a long history in the built environment and now that the time for new building is coming to an end, perhaps architects need to more fully embrace the sensibility of the interim.

There is a long tradition of interim inhabitation, it is what squatters do, and it is acknowledged by artists when they move, like pioneers, into an unpopular quarter of the city. More recently the idea of interim inhabitation has become part of the development process, protecting empty buildings from squatters and vandalism, beginning to build the brand of what comes next. We are interested in all of these examples and wish to explore ways in which the positive qualities of the interim can be extended so that the seeming inevitability of gentrification is deferred, perhaps forever.

We will work in a series of buildings in Zurich that are currently being provisionally occupied under different legal arrangements. We will begin by closely observing and recording current conditions, learning something about the relationships between creative programme and inventive spatial practice. By deploying a series of processes; to repair, to collect, to mark, to remove, to arrange, to support, we will work to develop the current contingent situation into something more robust. In this process we will engage with the existing networks of inhabitants, building owners and spatial/material arrangement, and challenge the social, legal and aesthetic limitations of architecture.

Prerequisites / notice

Group work only.
Critiques: Dates will follow
Costs: CHF 100.-- (besides the seminar week).


Does not take place this semester.
Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
Not offered in HS21.

052-1145-21L Architectural Design V-IX: Voluptas S1E7 Repetition/Difference (F.Charbonnet/P.Heiz) W 14 credits 16U F. Charbonnet, P. Heiz

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
This semester aims at both designing erratic hyper-contexts generated by hypothetical ruling incentives, and the obsessive recording of their past and present traces of erasures and becomings.

Objective
Objectives: Research & curation of contemporary concepts, articulation of a discursive argument, visual literacy & storytelling, image montage & composition, architectural drafting and projecting.

Incentives: Movies & scenario, territorial & urban scale, collectivity, situations & artefacts, socio-political dimension, critical position, contemporary conditions.

Steps: (1) Analyze a movie, research contemporary concepts, identify potentials, articulate a critical position. (2) Project an urban scenario on both the artefactual and the territorial scale, focusing on collectiveness and the socio-political aspects of society. (3) Express a critical position towards a contemporary condition by the means of such a fictive context in both image and plan. (4) Train rhetoric and argumentation, master drafting skills as well as image montage.
Architectural Design V-IX: Nothing but Flowers -

Penitimento, n. [pen-tuh-men-toh], plural pen·ti·men·ti [pen-tuh-men-tee].

Painting:
The presence or emergence of earlier images, forms, or strokes that have been changed and painted over. (https://www.dictionary.com/browse/pentimento [2021])

Repentir, s.m.
A.1. RELIG. Regret douloureux de ses péchés avec le désir de les réparer et de ne plus y retomber. Synon. contrition, repentance (véliou ou lliet). P. ext. Vil regret d'une faute, d'une erreur, d'une faiblesse. 2. P. ext. Regret d'une action quelconque.


“Since the trace is not a presence but the simulacrum of a presence that dislocates itself, displaces itself, refers itself, it properly has no site—erasure belongs to its structure. And not only the erasure which must always be able to overtake it (without which it would not be a trace but an indestructible and monumental substance), but also the erasure which constitutes it from the outset as a trace, which situates it as the change of site, and makes it disappear in its appearance, makes it emerge from itself in its production. The erasure of the early trace of difference is therefore the ‘same’ as its tracing in the text of metaphysics. […] The paradox of such a structure, in the language of metaphysics, is an inversion of metaphysical concepts, which produces the following effect: the present becomes the sign of the sign, the trace of the trace. It is no longer what every reference refers to in the last analysis. It becomes a function in a structure of generalized reference. It is a trace, and a trace of the erasure of the trace.” (J. Derrida, Margins of Philosophy, Différence, 1982 [1972])

Content:
Pursuing our rambling exploration on the lookout for urban environments beyond reasonable and more than ever considering humankind as embedded in, acting upon and dependent on its geological era, we shall look upon history’s intertwined layers and sediments as raw potential to be appropriated and composed with – joyfully disrespects scientific authenticity. The visionary Histor seeks, finds novelty in the old, rather than an unfounded assertion of the present with the past. This semester aims at both designing erratic hyper-contexts generated by hypothetical ruling incentives, and the obsessive recording of their past and present traces of erasures and becomings.

Repetition/Differenc:
invokes identity and sameness, evolution and change, patterns and habits, originality and copy, time and recurrence, beat and rhythm… all things seemingly constant, all shades of their endless variations. How may such abstract notions contribute to shape immortal processes and crystallize timeless and paradigmatic urban environments? The careful and critical consideration of architectural paragons, socio-economical dynamics, geopolitical shifts, further endowed with the lure of fiction, shall initiate new beginnings to alternate (hi)stories and cityscapes.

Prerequisites / notice
Group work only.
Introduction: 21.9.21, 10h, HIL G74
Critiques: Dates will follow.
Costs: 30 CHF per Student (besides the seminar week).

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Abstract
From the age of the dinosaurs, cars have run on gasoline
Where? Where have they gone?
Now, it’s nothing but flowers
(Talking Heads, 1988)

The studio will investigate and imagine nature in the metropolitan territory of Zurich. The results will be made public in the form of online investigative reportages, meant to inform design practices and public discourse on ecology and nature conservation.

Objective
NEW ECOLOGIES
New Eco Eologies is a studio series at Architecture of Territory dedicated to ecologising architecture. Ecological thinking, which foregrounds the interactions between organisms (or by extension between objects, or social and technical systems) and their environments, is applied in considering design practices in their social and environmental effects. The studio series is affiliated with the Future Cities Laboratory and the new Master of Advanced Studies MAS UTZ starting in the fall 2021. Citizens, experts, and fellow designers and artists will accompany us in the process.

PROCESS AND RESULTS
The semester consists of investigative journeys and intensive studio sessions. Architecture of Territory values intellectual curiosity, commitment and team spirit. We are looking for avid travellers and team workers, motivated to make strong and independent contributions.

Our approach enables students to work with a range of methods and sources pertaining to territory, including ethnographic fieldwork, interviews, literature research and essay writing, large-scale drawing techniques, photography, videography, and online publishing. Experts and guests will help us sharpen our skills and craft common agendas through debates. Students work in groups of two to three.

SEMINAR WEEK: PIONEERS OF CONSERVATION
Investigative journeys constitute the core of the project. The first studio day starts with an exploratory walk through the forested backstage of the Hängenberg. The investigations will continue throughout the seminar week, dedicated to pioneers of nature conservation. Foresters, gardeners, volunteers and veterans of nature associations, scientists, and environmental activists will be our guides. We will traverse the metropolitan territory of Zurich by foot, by bike, by bus and by train. The common trip is followed by a period dedicated to fieldwork in respective student teams. The seminar week takes place from October 24–30 (cost frame A). It is integrated, mandatory, and open to all interested students.

LECTURES SERIES: MY SPECIES
Within the lecture series ARCHITECTURE OF TERRITORY. Territorial Design running in alignment with the studio, four guest speakers engaged in fields ranging from art and landscape to bioethics and environmental philosophy, will address the theme MY SPECIES, approaching territory through the notions such as multispecies, coexistence, and diversity.

CREDITS
The semester offers the total of 19 credit points. The Design Studio with Integrated Discipline (Planning) 14+3 KP and the Seminar Week 2 KP.
We are often told that Nature is being lost, damaged and polluted, sacrificed to consumption habits and ambitions of urban development. We are told of the environmental crisis of planetary proportions, of the loss of species and the imminent collapse of the web of life. We hear appeals to preserve and respect Nature, to curb our resource use and manifest an ethos of care. Nature is the concept governing actions of individuals and societies, and yet, if we try to put our finger on “nature”, to situate it in our environments, it is slippery and far from clear. The politics of space and territory relies on both green arguments, as well as privileging of our own species. Nature is often not more than a convenient gesturing: the net loss or gain of forest; the carbon offsetting; the nature compensation, the green tech, the greenwash.

But nature is also a space of imaginary. As a concept, Nature has played a historical role for the human communities through its association with the divine, the primitive, the bestial, the corporeal, and the feminine. In Switzerland and other countries, the forming of nature conservation as a scientific discipline mirrored the industrialisation processes throughout out the XIX century as a specific reaction. Invigorated by aesthetic and patriotic sentiments, early activist movements deployed the industrial destruction of both “nature” and “homeland”. Gradually conservation efforts consolidated, working their way into institutional and land use frameworks. Much of nature conservation effort historically has been rooted in the nature-culture divide, an understanding where any product of human activity is seen as being separate from nature, and thus resulting in the production of landscapes cleared from human inhabitants and demarcated from human use. But different paradigms of conservation took hold as well. Some approaches have emphasised on the role of the human carer in the protection and a sustainable use of nature (through for example mining or logging). Others have explored rewilding of landscapes through the reintroduction of previously disappeared species.

In the seemingly pastoral, but essentially highly technological territory of Switzerland, the meaning and the role of nature is far from settled. Being woven into the territory, nature areas remain an object of multiple pressures and interests. As the failures of recent initiatives—the CO2-Gesetz, the Trinkwasser-Initiative and the Pestizidfrei-Initiative—have patently shown, there is little agreement on what kinds of nature are worth preserving, by whom, and how. As designers, we may add that, there is also a lack of environmental imagination, which ought to be explored.

In this semester we will investigate and imagine nature in the metropolitan territory of Zurich. We will analyse political, financial, cadastral and other entanglements between urban space and nature. We will engage in multispecies ethnography, tracing our relations with other species. We will engage with aesthetics, science, and the philosophy of nature. Focusing on selected sites, from the Rhine plains, through the fields of Weinfeld, the logistic valleys and leisure hilltops around Winterthur, to the forests and pastures of Zürcher Oberland, we will look at nature in its different incarnations—the protected biotopes, the nature monuments, the second natures and the third landscapes of the agglomeration, the cheap natures of industrial farming, and so on.

Students will write their own project briefs, and will develop territorial analysis and projects for the chosen sites. The takes form of a web-based investigative reportage. During the production we will work with GIS and CMS experts, a journalist, a data scientist, a videographer and a photographer. The results of the studio are delivered in the public forum, meant to inform design practices and public discourse on nature conservation.
The general aim of the course is to propose transformation strategies for existing learning environments on the campus of ETH in order to...

**Abstract**

Architecture defines the spaces in which we live and work in during every moment of our lives. We will study the large scale in which the work of an architect has an impact on the biggest possible amount of people. A house as big and complex as a whole village. The design work is understood as an investigation on the daily conditions of our times, through the media of architecture.

**Objective**

This semester the design studio will focus on the big scale. Students will develop a design based on a given competition brief and will deal with the theme through a critical approach.

Analysis of fundamental aspects of the given task, fast track design methods leading to alternative concepts should establish the strategic and factual basis for a critical understanding on how to deal with the big scale. The goal is to develop an individual and critical understanding of the topics and, just like in a real office, students will work individually towards a final collective output.

**Content**

Architecture defines the spaces in which we live and work in during every moment of our lives. We will study the large scale in which the work of an architect has an impact on the biggest possible amount of people. A house as big and complex as a whole village. The design work is understood as an investigation on the daily conditions of our times, through the media of architecture.

The brief and the site of actual competitions will be the starting point of the semester. In the studio, students will work individually during some design stages and they will work together during others. This collaboration is understood as a teamwork in which each participant has a clear task, different from the others.

Students will develop their design capacities, which relate specifically to the work in the large scale and they will develop their own individual and critical understanding of the challenges of our times. Throughout the semester there will be lectures and discussions with architects working on large commissions. Zaha Hadid Architects, Christine Binswanger, Bjarke Ingels and Ma Yansong will be guests of this semester and give some inputs.

**Prerequisites / notice**

Individual work and group work, whereof at least 3-4 weeks of group work.

Critiques: 19./20.10.; 16./17.11.

Costs: CHF 40.-- (besides the seminar week).

**052-1111-21L Architectural Design V-IX: Informal Learning Spaces**

W 14 credits 16U M. Kaijima, F. Persyn

(M. Kaijima / F. Persyn)

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php).

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

**Abstract**

What is a learning space at ETHZ? The studio supported by Innovedum, is jointly run by the Chair of Architectural Behaviorology and the NEWROPE Chair with the Chair of Cognitive Science. It develops from research and 1:1 mock-ups in HS2021 towards realizations of interventions in SS2022. Students tackle 3 environments: architecture studio space, semi-public library, and conventional classroom.

**Objective**

The general aim of the course is to propose transformation strategies for existing learning environments on the campus of ETH in order to create the appropriate conditions for reflexive learning, which is a type of learning in which one explores one's own experiences to become more conscious, open-minded, and self-critical. Students will study the existing space through the learning research methods to design and realize 1:1 mock-ups and interventions in 3 different sites of ETH to adapt the space's respective conditions to their educational purposes, and to enhance the actors' behaviors, on a human, material and natural level. Students' designs are framed within a larger understanding of learning spaces, based on theoretical and historical knowledge, and attentive site observations, as much as on the exchange with users and experts, in close collaboration with other students, teaching staff and stakeholders. They will be supported by 2 Senmonkas (Japanese experts), architect and carpenter Karl Rühle and textile designers Anne Masson and Eric Chevalier. Students further learn and improve their practical skills in the fields of research, representation and design, 1:1 detailing and building, guided jointly by both the Chair of Architectural Behaviorology and the NEWROPE Chair of Architecture and Urban Transformation. In all phases of the course, students will learn study the representation and communication tools from both chair’s expertise, such as Architectural Behaviorology, Design in Dialogue, Decision-making processes, Actor-Network drawings, sketches, models, 1:1, films or interviews, scientific report.

The learning goals correspond to the grading system of each chair. The final grade will be the average of both grades.

**Chair of Architectural Behaviorology**

Understanding of Architectural Behaviorology

Research

Design

Visualisation

Structure and Material

Submission delay

**Chair of Architecture and Urban Transformation**

Clarity and Independence of Position

Relevance regarding the case

Depth of engagement

Representation

Design in Dialogue

Mutual Collaboration

Personal Development

Grading percentage of the process of the study First mid review 35%, Second mid review 35%, Final review 30% (15% collective work, 15% individual work)
Introduction
Teaching and learning methods are evolving. The complexity of our lived reality demands new sets of skills and competencies to be integrated in education, especially in architecture, which is changing from a competitive model based on individual authorship to a complex, interdisciplinary challenge. Real-world problems urge universities worldwide to invest in pedagogical approaches that support exchange and reflexive learning, i.e. constant self-reflection based on our own experiences and positions. Experimenting, testing and taking strong, sometimes diverging positions need Safe Spaces that offer professional and emotional stability to turn confrontations and discussions into productive dialogues. These include informal spaces that invite a diversity of uses, where students and staff meet, exchange and inspire each other. In order to precisely integrate collaboration, self-management, positionality and collective evaluation into the teaching and learning methodology, we need spatial configurations that enable and promote diverse and flexible behavioural settings. For this reason, we collectively aim to transform and integrate informal learning environments in three existing situations at ETH Zürich:

(A) Studio space at the department of Architecture, ONA.
For this case study, 2 groups of 4 students will work on architecture studio spaces. During their education, architecture students are reflecting about a diversity of spaces and scales, often without taking into consideration their own learning environments. These spaces remain until today, with some exceptions, very generic, very often lacking attractiveness. How can the education of architecture benefit from a transformation of its spatial environment? How can this spatial transformation support students in testing their own positions regarding complex problems?

(B) Public library at the InfoCenter of the ETH Library, in the main building of ETH
ETH Library offers a range of services that are unfortunately largely unknown to users. For this case, 2 groups of 4 students will think about the following questions: How could the spatial environment of the library offer both, an understanding and a visibility of the provided services? How can the functions of a library be combined with a learning space itself? How to manage acoustic or representational issues while offering the necessary representative freshness? Students are invited to collectively think about possibilities of the future of the library considering the different expectations of departments’ staff, students, librarians and public.

(C) Classroom at the Department for Environmental Systems (D-USYS), with the Transdisciplinary Lab (TdLab)
During the Course “Tackling Environmental Problems” students of D-USYS work in groups and in close collaboration with different stakeholders for solutions of environmental issues. Their methods include role plays and performative presentations that enable participants to reflect on different positions in complex situations. 2 groups of 4 students will accompany the course and observe the spatial settings and use of a rather conventional classroom of ETH. How do staff and students work in groups in classrooms? What kind of intervention could strengthen collaboration? Which spatial configuration functions both, as a representative stage, and as a safe ground to strengthen roles and communicate information?

Lecture notes
Schedule
Phase I Week I-V: Research History, Research, Observation, Documentation and Representation of the 3 sites.
Week VI: no class during Seminar Week
Week VII-XI: Intervention Design, Implementation and Observation of 1:1 mock-ups in all 3 sites
Week XII-XIV: Translation Documentation, evaluation, reflection and translation of results into a Research Report and a 1:1 collective installation in Studio.

Assignment and deadlines
Week V: Research Drawing & Documentation, Process Book*, Design of Presentation Setting
Week XI: 1:1 Mock-up, Design Drawing, Process Book*, Mock-up Re-enactment on site
Week XIV: Mock-up collective 1:1 installation in studio, Process Book, Research Report*
*Process Book and Research Report are individual work.

Literature

Prerequisites / notice
Group and individual work, whereof at least 5 weeks group work.

Introduction: 21.09.21
Mid-term review 1: 20.10. 21
Mid-term review 2: 01.12.21
Final Review: 23.12.21

Costs: 100 CHF (besides the seminar week).

Students could work for int. Disziplin class below.
Name: Architecture and Urban Design
LV-Nr.: 051-123319L

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management assessed

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

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed
### Design and Architecture

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>052-0511-00L</td>
<td>Planning Strategies for Complex Buildings Using the Example of Health Facilities (HS)</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>T. Guthknecht</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Independently written scientific paper concerning a subject of planning of complex buildings - such as health facility planning and design - with special focus upon the dynamic changes in this context and the related planning and building reactions to them.</td>
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<td><strong>Objective</strong></td>
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<td>The objective is that the students engage in a debate of a differentiated functional planning as a basis for complex buildings which are to be successful functionally, operationally and in design. On the basis of a given scope of themes the students carry out research aiming for possible improvements for example in health facility planning. The scope of subjects is announced at the beginning of each semester.</td>
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<td><strong>Content</strong></td>
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<td>Complex buildings such as health care buildings are subject to constant change. In a new hospital building 60% of the diagnostic and treatment areas are subject to building changes within the first 10 years of operation. Architecture has to develop concepts which accommodate this level of dynamics into the building structure in a better way. In the coming years this need for adaptability is going to be challenges even further by the even more reducing health care resources. The paper should discuss in this context a specific question in detail by analysing problems and developing and discussing potential planning solutions.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Presentations of the lecturer and guests will be available</td>
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<tbody>
<tr>
<td>052-0513-00L</td>
<td>Spatial Concepts in Film and Architecture (HS)</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>M. Bächtiger Zwicky, A. Gigon</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The course deals with spatial phenomena at the interface of film and architecture. The alternating influence of these two media will be analyzed, the dispositions of perception and effect will be compared and thus will sharpen the view for a architectural way of looking at space.</td>
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<td><strong>Objective</strong></td>
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<td>The examination of filmic space situations and performance discloses new perceptions of architecture which will be studied on behalf of film analyses and experimental topics. During the course space-effective creative means such as editing or framing will be introduced and discussed under perceptive aspects. Mediality within spatial perception can thus be integrated into a development of cultural history and leads towards a conception which goes beyond the limits of architecture and stimulates new processes of design.</td>
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<td></td>
<td><strong>Content</strong></td>
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<tbody>
<tr>
<td>052-0521-00L</td>
<td>3D Scanning and Freeform Modeling (HS)</td>
<td>W</td>
<td>2</td>
<td>2U</td>
<td>A. Grüninger</td>
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<td><strong>Limited number of participants.</strong></td>
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<td>Enrolment in agreement with the lecturer only (<a href="mailto:grueninger@arch.ethz.ch">grueninger@arch.ethz.ch</a>).</td>
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<td><strong>Abstract</strong></td>
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<td>Design in virtual space - 360 ° Reality to Virtuality (052-0523-00L) meets 3D Scanning &amp; Modeling (052-0521-00L)</td>
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<td><strong>Objective</strong></td>
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<td>Our program this semester is to try out virtual design with the technology of VR glasses in the form of independent work. We make every effort to ensure that new design techniques are taught at the ETH and that they find their way into design practice. The aim is to be able to scan and digitize the existing building structure and then to learn to expand and adapt it with the virtual VR Sketch Tool. It is a completely new technology for us architects. First we have to calibrate our senses and think differently in order to understand the possibilities of the tools. Finally, we will work together on a submission of VR architecture and present it in our showroom in HIL F.</td>
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<td><strong>Content</strong></td>
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<td>Our program this semester is to try out virtual design with the technology of VR glasses in the form of independent work. We at the Chair of Architecture and Art endeavor to ensure that new design techniques are taught at the ETH and find their way into design practice. The aim is to be able to scan and digitize existing building structures and then to learn to expand and adapt them with virtual VR sketch tools. It is a completely new technology for us architects. First we have to calibrate our senses and think differently in order to understand the possibilities of the tools. Finally, we will work together on a submission of VR architecture and present it in our showroom in HIL F.</td>
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We will run the courses as follows this semester.
1. Both courses are combined. (2 x 2 ECTS points & please enter both courses)
2. Present tense lessons (online or physically according to the instructions of the school management, Mondays 2 p.m. to 4 p.m. (Course time 3D Modeling)
3. Self-study Mondays from 12 noon to 2 pm (course time 360 ° Reality to Virtuality) in self-study or whenever you can find the time.

We will provide Oculus Quest 2 glasses for each course participant. To register for the “virtual design” course, a deposit fee of CHF 200.00 is required for the Oculus Quest 2 VR glasses. This deposit must be submitted to the professorship no later than 2 weeks before the start of the course. This will also give you the Oculus Quest 2. (Maria Hil F 46/48, every Monday and Tuesday afternoon)
The glasses remain in your possession until December 20th, 2021 and you have a reserved place in the course. In the event of loss or defect without guarantee coverage, you will be charged CHF 510.00. Less the prepaid deposit of CHF 200.00
If you have your own Oculus Quest 1 & 2 VR glasses, you can also be there. When registering in the system, please provide a separate e-mail to rolle@arch.ethz.ch. Of course, there are no custody fees.
Prerequisites / notice

Enrolments need the lecturer’s allowance.

To enroll in the course, please consult the lecturer: Adi Grüninger; grueninger@arch.ethz.ch

Please send us a letter of motivation, stating your aspirations, goals / wishes for this elective.

Email to: rolle@arch.ethz.ch
CC: grueninger@arch.ethz.ch
kiryk@arch.ethz.ch

Tools where we use:
Gravity Sketch
Reality capture (3D scan program)
Oculus Quest 2
USB for Oculus Link (Beta Oculus Air)

We will use these tools and learn «design in virtual space» on the joint journey.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0523-00L</td>
<td>360° - Reality to Virtuality (HS)</td>
<td>2</td>
<td>2G</td>
<td>K. Sander</td>
</tr>
<tr>
<td>Abstract</td>
<td>Design in virtual space - 360° Reality to Virtuality (052-0523-00L) meets 3D Scanning &amp; Modelling (052-0521-00L)</td>
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<tr>
<td>Objective</td>
<td>The goal is to 3D-scan an existing space and use it in VR as a context for further design. First, we learn the tools; then we work on an architectural VR-project; at the end of the course, we present the works in our exhibition space in HIL F. Every student gets Oculus Quest VR-Headset to work with at home during the semester.</td>
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<tr>
<td>Content</td>
<td>We focus on virtual reality design process and create our own spaces using VR-headsets. We hope that this new technologies will change the design of architecture in the near future and will influence the learning process at ETH as well. The goal is to 3D-scan an existing space and use it in VR as a context for further design. First, we learn the tools; then we work on an architectural VR-project; at the end of the course, we present the works in our exhibition space in HIL F. Every Student gets Oculus Quest VR-Headset to work with at home during the semester.</td>
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Prerequisites / notice

Course requirements:
Both courses are connected “360 – Reality to Virtuality” and “3D-Modeling”
Please register for both courses:
“360 – Reality to Virtuality” (052-0523-00L) and “3D-Modeling” (052-0521-00L) (2x 2 ETCS)
Classroom-teaching (online or physical meetings, Mondays, 14:00 – 16:00) Self-teaching, research etc. (Mondays 12:00 – 14:00, or whenever you have time)

Please send us your short letter of motivation to Nicolas Rolle: rolle@arch.ethz.ch
Tools:
Gravity Sketch
Photogrammetry 3D-scanning (Reality Capture)
Oculus Quest 2
Oculus Link (USB-C cable)

052-0525-00L Material-Workshop (HS) 

Abstract This elective course is not taking place in HS21.

Objective The elective is organised as a laboratory where one particular material will be explored on a theoretical and practical level. During this study the contemporary architectural potential of the material will be tested and applied.

Content The elective is organised as a laboratory where one particular material will be explored on a theoretical and practical level. During this study the contemporary architectural potential of the material will be tested and applied.

Prerequisites / notice Is not offered in HS21.

052-0535-00L Model and Design (HS)

Max. Teilnehmerzahl: 16

Abstract The course Model and Design teaches architectural model building in an explorative way through systematic experiments and the development of corresponding methods in design.

Objective The primary pursuit is an in-depth study of three-dimensional form, color, material and composition along with the practical development of your own technical and artistic competences.
### 052-0537-00L 3D printing for the Architectural Design (HS)

**Prerequisites / notice**
- Free Drawing (HS)  
- Number of participants limited to 35.

**Abstract**
Drawing is an important tool to develop and illustrate the artistic ideas and abilities of students. Different techniques and methods will be tested.

**Objective**
Development of individual expression in the realm of drawing; artistic flexibility and skill in the areas of working strategy and aesthetic impact.

**Content**
Development of individual expression in the realm of drawing; artistic flexibility and skill in the areas of working strategy and aesthetic impact.

**Number of participants:** Limited

**Application via e-mail:** Maude Léonard-Contant <leonard@arch.ethz.ch>

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### 052-0549-00L Hybrid Modeling: 3D-Printing for the Architectural Design (HS)

**Prerequisites / notice**
- Free Drawing (HS)  
- Number of participants limited to 35.

**Abstract**
3D printing is a versatile representation tool for illustrating a design idea. This course teaches and practices how the design process can benefit greatly from 3D printing.

**Objective**
After the course, students will be able to use 3D printers and software programs like ArchiCAD.

**Content**
The course is suitable for complete beginners who have never used 3D printers. No previous knowledge in ArchiCAD is required. The use of ArchiCAD and 3D printing is required.

**Lecture notes**
In the first half of the semester, I will explain how to model and print an urban context and urban study.

In the second half, there will be an opportunity to participate in elective exercises or to benefit from the lecturer as a 3D printing coach for the respective design studio.

**Prerequisites / notice**
Knowledge of 3D printing technology is not required.

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### 052-0517-21L Theory and Practice: Heterotopia, Referential Space and Spatial Effects

**Prerequisites / notice**
- Theory and Practice: Heterotopia, Referential Space and Spatial Effects

**Abstract**
In 1967, Foucault showed certain entanglements of space with his concept of heterotopia; a little later, Pierre Bourdieu established a multidimensional space sociologically with his concept of field. The seminar also discusses such intertwining in current local situations and tries to think about potentials for spatial policy practice.

**Objective**
The students gain insight into the spectrum of epistemological and perceptual theories, learn to read them and analyze and critique their respective requirements. From this work an object relationship model is developing in progress, which serves self-examination in the design process as well as the evaluation of architectural situations in general and in particular. The writing of "scientific diaries" in which the contents of the colloquium are combined with the everyday experience of the students in free form, trains the concentrated result-oriented thinking in general, as well as in architectural situations. The special form of the writing of the "scientific diary" leads abstract Theory together with the experience of the students and make the knowledge creatively available in their own way.

**Content**
In 1967, Foucault showed certain entanglements of space with his concept of heterotopia; a little later, Pierre Bourdieu established a multidimensional space sociologically with his concept of field. The seminar also discusses such intertwining in current local situations and tries to think about potentials for spatial policy practice.

**Prerequisites / notice**
Cooperation in the form of discussions and scientific diary.

The additional personal work (besides the course) is about 20 working hours for the creation of a scientific journal, individual deepening and filming!

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### 052-0533-00L New Focal Points of Construction: Steel Constructions

**Prerequisites / notice**
- New Focal Points of Construction: Steel Constructions

**Abstract**
The elective subject "New focal points of construction" investigates the complex interaction of construction elements by means of exemplary architectonic tender points such as base, wall, chamber, roof etc. The comparative analysis of built constructions serves as a basis for further development of hypothetical future constructions.

**Objective**
The target of the course is the understanding of the impacts of material, technology and construction to the architectural education of constructive points. With comparative analysis of built constructions of high architectonic relevance, by means of exemplary building elements such as base, wall, chamber, roof etc., the genesis of constructive building parts, the interaction of the building elements and stand of technique for the most of common constructive tender points is imparted. The conjunction to current constructive methods and basic conditions enables a critical evaluation of the constructive Status Quo within the contemporary producing architecture as well as a perspective to new konstruktive education.

**Content**
- Lecture:
  1. Comparative analysis for derivation and understanding of the constructive points base, wall, chamber, roof etc.
  2. Description of current level of technique, typical methods, and set of problems.
  3. Coloquium with guests of producing and processing companies.

- Exercise:
New formulation of a future constructive point as a result of a diagnostic work.

**This course (ends with «00L») can only be passed once! Please check this before signing up.

https://www.buk.arch.ethz.ch/Lehre/VorlesungenNKOS2021
The Richti-Areal was created and advertised as fulfilling the highest demands that can currently be made on architecture and planning by...

The aim is a well-founded examination of a clearly formulated question.

E. Christ, F. Charbonnet, Huizinga, Johann, "Homo Ludens" Formalistic Analysis of the Architecture of the Neo-

Lecture Series Design and Architecture: Architecture

3 credits

2A

P. Heiz assessed assessed

Obtaining knowledge from architectural practice after 2020. From Game Theory to Dices, touching Go, Hide-and-seek or Sims, a multitude of games and acts of play will serve as standing points for

Lecturers

3G

Territories of Play - Surveying Architecture Through

Game Design (HS)

2 credits

2S

P. Heiz, F. Charbonnet, F. Morpurgo Veiga

This course offers an introduction to the theoretical frame of the seminar through three lectures; by a game designer, by an architectural historian or architect, and by the seminar's tutor. The theoretical works and authors which make up the core of the seminar - Jesse Schell, Johan Huizinga and Kate Salen & Eric Zimmerman - will thus be presented and analysed, hinting at possible bridges to a critical analysis of architecture and the built environment through its decomposition into Mechanics, Aesthetics, Narrative and Technology, the four pillars of game design.

Students will be invited to select a game, dissect it according to the theoretical input previously received, and select a key aspect of it. This key aspect will in turn be used as lenses through which students should analyse and question their reality, a milieu of their own choice: from the spaces and urban situations forming their daily routine in the city, to their hometown or fetish city. From this analysis, an essay presenting and defending their hypothesis of reading of their milieu through gaming should emerge.

The writing will be conducted during the seminar's attendance time. Students are to produce a coherent, ludic publication compiling the classes' essays into an accessible survey.

Literature

Huizinga, Johann, "Homo Ludens"

Sicart, Miguel, "Play Matters"

Salen & Zimmerman, "Rules of Play"
Investigate design research methods through analyses of architectural examples that focus on repair.

Peter Maxwell. 'A Dangerous Breed'. Originally published in FORM 246, 2013

Summer School: Under the Landscape - Young Makers Gathering

Does not take place this semester.

The garden project has been an integral part of the teaching curriculum at Studio Tom Emerson, involving over 300 students in its conception over the past five years. On the one hand it is a design project, a pedagogical tool, focusing on ideas of construction, reuse, renovation, rejuvenation, maintenance and subtraction, yet we also see it as a form of constant and continuing research into our interactions with the dynamic processes of time and passing seasons. Can we practice architecture, with the care of a gardener?

In this weekly elective course, the goal will be to look at repair as a possible method for a new kind of design. As a disciplinary response in an era of climatic change, it is envisioned that this study should pose a range of questions to challenge conventional building economies and the durability of the constructed environment. We will interrogate and look for ways of improving and repairing standards of construction industry ranging in scale from urban to material choices. The methods developed and gathered should become an outline conception over the past five years. On the one hand it is a design project, a pedagogical tool, focusing on ideas of construction, reuse, renovation, rejuvenation, maintenance and subtraction, yet we also see it as a form of constant and continuing research into our interactions with the dynamic processes of time and passing seasons. Can we practice architecture, with the care of a gardener?

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As part of a restoration project by the interdisciplinary research collective "Boulouki" on the Greek island of Thirasia, site-specific craft techniques are being revived. The focus of the investigation is the abandoned cave settlement Agrilia, the restoration of the natural stone path to the settlement with accompanying dry stone walls and two cisterns sealed with pozzolanic plaster.

- Getting to know traditional craft techniques, the corresponding construction principles and material properties through implementation on a 1:1 scale
- Understanding of the local relationships between landscape and type of settlement
- Interdisciplinary exchange with participating specialists
- International exchange with Greek students

The interdisciplinary research collective "Boulouki" (www.boulouki.org) carries out restoration projects in Greece every year with student participation. The group, led mainly by young architects, is well networked with universities and specialists, prepares the events meticulously and tries to embed them in the local craft and social context.

As part of the workshop, the path to the abandoned cave settlement Agrilia will be restored, which is centrally located on the island of Thirasia in a valley. The natural stone paving of the path and the adjacent dry stone walls will be exposed and repaired, as will two cisterns of the water supply system. These are sealed with plaster, which has a special strength and water resistance due to its aggregates made of local pozzolan earth (Santorin earth, trass lime). The restoration work takes place in the mornings and is accompanied by local craftsmen and apprentices.

The type of settlement in Agrilia is uniquely dependent on the local (geological) conditions. The settlement should be understood in its entirety (connections between geology, agriculture, water drainage, architecture, volcanic materials, etc.). An artistic and creative examination of the local materials is also sought. For this purpose, seminars and lectures are organized in the afternoons and evenings with the participation of craftsmen, archaeologists, geoarchaeologists, agronomists, the rector of the Athens School of Art and of course architects.

Please check this before signing up.
This course (ending with «00L») can only be passed once!

In the course of organizing the workshop, it was possible to bring together older local craftsmen with young apprentices, who were taught traditional techniques for a month before.

### History and Theory of Architecture

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0821-00L</td>
<td>Architecture and Photography (HS)</td>
<td>W</td>
<td>2</td>
<td>4S</td>
<td>T. Wootton</td>
</tr>
<tr>
<td></td>
<td>A letter is requested with the preference for one of the groups until 17.9.21. For details see course description!</td>
<td></td>
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</tbody>
</table>

- Representation of architecture is inextricably linked to photography since the mid 19th century. As buildings are commonly discussed on the basis of images, understanding their technical origin is key to reading and making them. By teaching students how to use a 4x5" view camera, the artist and photographer Tobias Wootton will introduce different techniques of 'thinking through the lens'.
- Knowledge of architectural photography
- History, theory and practice of photography in relation to architecture

- Course dates s. room reservations!
  - Group 1: Thursdays 16:00 - 20:00; Group 2: Fridays 14:00 - 18:00

- Students will be selected on the basis of a motivation letter.
- Deadline: 10.9.21, 12:00 h, to wootton@arch.ethz.ch.
- Please also state a preference which day suit you best:
  - Group 1: Thursday evening
  - Group 2: Friday afternoon

- Course dates s. room reservations!

- Students will be selected on the basis of a motivation letter.
- Please also state if you have a preference for the Thursday or the Friday class.
- Deadline: 17.9.21, 12:00 h, to wootton@arch.ethz.ch.

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<tbody>
<tr>
<td>052-0847-00L</td>
<td>Experiments on the Spatial Perception and Spatial Cognition of Architects (HS)</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>A. Gerber</td>
</tr>
<tr>
<td></td>
<td>This course (ends with «00L») can only be passed once! Please check this before signing up.</td>
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</tbody>
</table>

- The course deals with the question of how architects perceive architectural and urban space and how their spatial imagination can be grasped empirically. This before the tradition of comparable investigations in history and the theory of architecture. In the seminar we work with Unity.
- Students gain insight into the history and theory of scientific spatial research and architectural aesthetics as well as into the related contemporary cognitive sciences (cognitive psychology and neuroscience). They develop an original question about the perception of space and the spatial imagination of architects, which they verify in an experiment. This experiment will be realised in a video game.

- The course presents the "state of the art" of cognitive sciences and their relevance to architecture against the background of the historical analysis of architectural theory with these topics. Discussions take place on existing experiments and theories that pertain to architecture and use them to develop original, empirical experiments from which a sound understanding of architecture and design can be gained.
- Students will work also with Hololens and thus investigate upon the boundary between the experience of "real" and of "virtual" spaces.

### Autumn Semester 2021

- International exchange with participating specialists
- Understanding of the local relationships between landscape and type of settlement
- Interdisciplinary exchange with participating specialists
- International exchange with Greek students

In the course of organizing the workshop, it was possible to bring together older local craftsmen with young apprentices, who were taught traditional techniques for a month before.

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<th>Number</th>
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<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>052-0813-21L</td>
<td>History, Criticism and Theory in Architecture: Things of Postmodernity</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>D. Spina, L. Stalder</td>
</tr>
</tbody>
</table>

Please also state your interest in Hololens.

- Accommodation costs EUR 400 for two weeks.
- Independent catering;
- Travel expenses individually.

Deadline: 17.9.21, 12:00 h, to wootton@arch.ethz.ch.
Please also state if you have a preference for the Thursday or the Friday class.

Students will be selected on the basis of a motivation letter.

- Course dates s. room reservations!

- This course (ending with «00L») can only be passed once!
Communication

The doors of the D-Arch have been closed for over a year. We stayed at home and pretended digital teaching was still our concern.

B. Seidel

Concepts and Theories

Theory of Architecture: What Drawings Did and Do
2 credits

L. Stalder,

Seminar Architectural Criticism: The Other Institution,
C. Brothers

assessed

2S

assessed

assessed

H. Romakin

In this seminar, writing is taught as a craft, and text work as well as journalistic strategies for its publication are dealt with intensively. The seminar meetings will convene as often as possible in the drawing study rooms in and around Zurich, including the Archives of ETH, the Graphische Sammlung of ETH, the Kunsthaus Zurich, and the Stadthaus Zurich.

The function of drawing changed with the advent of digital modeling, which made hand drawing marginal at best to both firms and schools. The seminar considers both historical techniques of drawing as well as a range of conceptual approaches and functions, and its possible future within the altered profession of architecture.

In light of current conditions, the seminar considers both historical techniques of drawing as well as a range of conceptual approaches and functions, and its possible future within the altered profession of architecture.

It will take an interest not only in drawing as a practice, but also as a representational tool. It will adopt a critical attitude towards the traditional architectural conventions of plan, section, elevation, axonometric drawing and challenge students to think about how those conventions might be interrogated or undermined.

The chronological scope of the seminar will be very broad. The professor’s expertise is in Renaissance drawing, however the seminar aims to take advantage of the resources available in Zurich which include everything from fifteenth century drawings to the present.

Interested students will have the opportunity to take part in the conception and organization of a conference on the topic of drawing, including both architects and historians.

There will be some assigned reading, but relatively little, focused on historical techniques and special topics in the history of drawing; most of the historical background will be conveyed through the professor’s presentations and select guests, and most of the work will be drawing exercises.

Prerequisites / notice

Students will be expected to complete regular drawing assignments every other week (for a total of 5 per semester); these will be the basis of the final grade and most work will be concentrated towards the beginning and middle of the semester to avoid conflict with studio work.

Because the class will be located at various sites around Zurich, students should allow 30 minutes before or after class for travel.

Adaptability and Flexibility

When we think of postmodern architecture, we often think of concepts (‘superficiality’, ‘pastiche’, ‘simulacra’, and so on) and not so much of ‘things’. In other words, our analysis of postmodern architecture tends to focus on the immaterial and ignore all the material objects that these buildings are made of, and that distinguish them from their predecessors. This bias makes us underestimate the importance of mundane, humble ‘things’ in the design of these buildings and our lived experience of them. Because underpinning the transformation of architecture over the last fifty years was not just a generic shift in our worldview, but also the introduction of discrete technological objects which functioned as vehicles for the ideological, cultural, and societal changes that we associate with the postmodern turn.

Following this proposition, this course examines postmodern architecture through the analysis of sixteen ‘things’ and the legal, material, and technical networks attached to them: mirror, escalator, ramp, TV screen, neon lamp, plant, glue, CCTV, cladding panel, plasterboard, shipping container, vending machine, corporate art, solar panel, computer, and cinder block. We will do so by reviewing a large body of literature on the ontological, epistemological, and social politics of things and matter more in general. Readings will include key works in architectural history, semiotics, actor-network theory, new materialism, and postmodern theory. Students successfully completing the course will be able to read buildings from an object-oriented perspective.

052-0815-21L Seminar Architectural Criticism: The Other Institution, W
Part II (A. Stahl)

2 credits

A. Stahl, L. Stalder, V. Villardebo Sacchetti

Abstract

The doors of the D-Arch have been closed for over a year. We stayed at home and pretended digital teaching was still our concern. Meanwhile, over 4 million people worldwide died as a result of Corona, and the climate crisis is advancing, our construction industry is responsible for 38% of CO2 emissions. The time has never been so pressing. Let’s start critique the status quo. Let’s start writing.

Objective

In this seminar, writing is taught as a craft, and text work as well as journalistic strategies for its publication are dealt with intensively. The research materials that were put together by the students in part I of the seminar last semester will serve as a basis: We will deal with mental health issues from before and during the pandemic, as well as the absence of ecology in teaching, among others.

052-0817-21L Theory of Architecture: What Drawings Did and Do
2 credits

A. Stahl

W

C. Brothers, L. Stalder

Abstract

For centuries, architectural drawings have been at the center of the profession: how architects come up with ideas, share them with clients, and communicate with builders. The seminar takes the point of view that hand drawing can still be a useful instrument for the architect, and that the ways how may be understood in part through a study of past drawings, studied in the original.

Objective

The seminar meetings will convene as often as possible in the drawing study rooms in and around Zurich, including the Archives of ETH, the Graphische Sammlung of ETH, the Kunsthaus Zurich, and the Stadthaus Zurich.

Students will develop a knowledge of techniques of historical drawings from the Renaissance forward, as well as a conceptual understanding of their uses, and the different graphic strategies adopted by draftsmen in response to varying conditions, materials, and aims. They will also have a chance to explore a range of approaches to making their own drawings, when possible in response to the earlier drawings we examine. The course will challenge students to consider what the future role of hand drawing could be for the architect.

Content

The function of drawing changed with the advent of digital modeling, which made hand drawing marginal at best to both firms and schools. In light of current conditions, the seminar considers both historical techniques of drawing as well as a range of conceptual approaches and functions, and its possible future within the altered profession of architecture.

It will take an interest not only in drawing as a practice, but also as a representational tool. It will adopt a critical attitude towards the traditional architectural conventions of plan, section, elevation, axonometric drawing and challenge students to think about how those conventions might be interrogated or undermined.

The chronological scope of the seminar will be very broad. The professor’s expertise is in Renaissance drawing, however the seminar aims to take advantage of the resources available in Zurich which include everything from fifteenth century drawings to the present.

Interested students will have the opportunity to take part in the conception and organization of a conference on the topic of drawing, including both architects and historians.

There will be some assigned reading, but relatively little, focused on historical techniques and special topics in the history of drawing; most of the historical background will be conveyed through the professor’s presentations and select guests, and most of the work will be drawing exercises.

Prerequisites / notice

Students will be expected to complete regular drawing assignments every other week (for a total of 5 per semester); these will be the basis of the final grade and most work will be concentrated towards the beginning and middle of the semester to avoid conflict with studio work.

The seminar will be limited to 24 students; groups of 12 will visit the drawing rooms while the other group does a drawing exercise lead by a teaching assistant. Interested students should email the professor indicating the reason for their interest and any drawing experience or studio art background.

Because the class will be located at various sites around Zurich, students should allow 30 minutes before or after class for travel.

052-0825-21L Special Questions in History of Art and Architecture:
W

“Protect Us From What We Want”

2 credits

B. Seidel

2S

H. Romakin

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

assessed

Domain B - Method-specific Competencies

Analytical Competencies

assessed

Decision-making

assessed

Domain C - Social Competencies

Communication

assessed

Cooperation and Teamwork

assessed

Domain D - Personal Competencies

Adaptability and Flexibility

assessed

Creative Thinking

assessed

Critical Thinking

assessed

Integrity and Work Ethics

assessed

Self-awareness and Self-reflection

assessed

Self-direction and Self-management

assessed
Have you ever resisted the urge to travel and tried to imagine your travel? That’s the experimental set up for the seminar. The idea is to split the participants of the seminar into two groups: travellers and non-travellers. In pairs (tandem partnerships), they will be interconnected through various media. The final outcome will be a video essay, which combines their findings.

Imagination and abstraction are important skills of the architectural profession. The seminar aims to train students in precise descriptions and to expand them with fictional content. Discussions will elaborate the advantages and disadvantages of traveling and being on-site. In the two different attentions of the students’ tandem work, the digital experience and the real experience meet. Discussed are those elements and facts that benefit or come off worse due to the different perceptions.

The seminar participants will be divided into 2 groups: A) Students who are “travellers”, i.e. who participate in a seminar trip of any professorship; and B) “non-travellers”, students who do not take a seminar trip in this semester. Mixed tandems will be formed among the participants. First, the students will be prepared for the seminar week in an architectural history introduction to research trips, discussion of texts read together. Afterwards, the seminar group will work with the tutors to identify questions and topics for the upcoming trips, and discuss possible tools and practices for “travellers” and “non-travellers”. During the seminar trip, the tandem partners are in contact with each other. Both groups are given different tasks: The “travellers” document the trip, select the collected footage and upload it to the online platform while tagging it. The “non-travellers” perform a commentary function on the resulting footage and conduct in-depth thematic research. After the seminar trip, both groups meet again in the seminar room to exchange and discuss their experiences. Together, they review and classify the footage that has been created and collected. From this, the assignment is developed and considered with the students: The hybrid journey is to be produced in the format of a video essay by the tandem partners as a semester achievement under the supervision of the tutors.

Required reading will be made available as a download for registered participants. In addition to the seminar, we assign a “Vertiefungsarbeit” for the Video essay.

Seminar 1 (23/09) – Introduction
Seminar 2 (30/09) – Introduction
Seminar 3 (07/10) – Gender Perspectives
Seminar 4 (14/10) – Gender Perspectives
Seminar 5 (21/10) – Gender Perspectives
(28 Oct - no class, seminar week)

Seminar 6 (04/11) – Mid-term Review
Seminar 7 (11/11) – Urban Sociology Perspectives
Seminar 8 (18/11) – Urban Sociology Perspectives
Seminar 9 (25/11) – Urban Sociology Perspectives
Seminar 10 (02/12) – Special Workshop: Mixing Perspectives
Seminar 11 (09/12) – Final Review

Scans of the texts that need to be read before each lecture will be provided in digital form at the start of the semester via the website of the Chair of the History and Theory of Urban Design.

Abstract
Lecture notes
Prerequisites / notice

Seminar History and Theory of Urban Design: The City
Lived - Unlocking a Multidisciplinary Discourse

For students from the 3rd semester

4 credits

C. Nuijsink

2S

Autumn Semester 2021

Page 98 of 2152
**Creative Thinking**

Students will be introduced to the concepts of the commons and musha’, they will critically explore the theory of Hadi Al-Alawi and its Asian influences, as well as the context in which this theory was produced, and will reflect on it based on diverse experiences.

**Requirements:**

- Not eligible as a compulsory GESS Elective for students of D-ARCH.
- Not eligible as a Compulsory GESS Elective for students of D-ARCH.

**Taught competencies**

<table>
<thead>
<tr>
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<tr>
<td>Analytical Competencies</td>
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<tr>
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<tr>
<td>Critical Thinking</td>
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</table>

**Literature**


This course is offered mainly to master’s students or students from the 3rd semester.

**Objective**

- Active participation in the course: 10%
- Mid-term assignment: 40%
- Final assignment: 50%

**Taught competencies**

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### PhD Teaching: Beijing to Baghdad - Communism/Communism

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<tr>
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**Objective**

Students will be introduced to the concepts of the commons and musha’, they will critically explore the theory of Hadi Al-Alawi and its Asian influences, as well as the context in which this theory was produced, and will reflect on it based on diverse experiences.
The commons has been gaining traction in architecture and beyond, including in architecture, both as theoretical framework and as self-standing subject for examination. The trailblazing work of Elinor Ostrom has won her the Nobel Prize in economics in 2009. Radical, politically engaged researchers, such as David Harvey, Massimo De Angelis, and Stavros Stavrides, have taken up the topic of the commons as an institution of revolutionary potential. This course will bring a different perspective into conversation, namely the work of Had Al-Alawi, a prominent Iraqi scholar who wrote, towards the end of the 20th century, on the concept of musha’a (an Arabic word that closely resembles the commons). Based on pan-Asian history, and focusing on Chinese and Islamic civilizations, Al-Alawi theorizes the musha’/commons and musha’/yya (communalism) as central to communism, and argues that these practices are historically rooted in Asia. In this approach, he is influenced by Maoism and its relationship to Taoism—an ancient Chinese philosophy. We will critically explore the theory of Al-Alawi, situate in its historical and intellectual context, and reflect on it in relation to various experiences and theorizations of commons and communities around the world, past and present.

**Taught competencies**

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

**Prerequisites / notice**

During Seminar Week. 4 days, 6 hours per day. The first hour will be dedicated to the lecture, two hours for structured group discussion, and three hours for development of work, alternatively including another 1-hour lecture. The last day will involve the student presentations of their work.

**Content**

The commons has been gaining traction in architecture and beyond, including in architecture, both as theoretical framework and as self-standing subject for examination. The trailblazing work of Elinor Ostrom has won her the Nobel Prize in economics in 2009. Radical, politically engaged researchers, such as David Harvey, Massimo De Angelis, and Stavros Stavrides, have taken up the topic of the commons as an institution of revolutionary potential. This course will bring a different perspective into conversation, namely the work of Had Al-Alawi, a prominent Iraqi scholar who wrote, towards the end of the 20th century, on the concept of musha’a (an Arabic word that closely resembles the commons). Based on pan-Asian history, and focusing on Chinese and Islamic civilizations, Al-Alawi theorizes the musha’/commons and musha’/yya (communalism) as central to communism, and argues that these practices are historically rooted in Asia. In this approach, he is influenced by Maoism and its relationship to Taoism—an ancient Chinese philosophy. We will critically explore the theory of Al-Alawi, situate in its historical and intellectual context, and reflect on it in relation to various experiences and theorizations of commons and communities around the world, past and present.

**Prerequisites / notice**

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**Taught competencies**

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

**Prerequisites / notice**

To follow
Students have to attend regularly at the seminar inside and outside of ETH, to take part in the discussions and to prepare the selected texts. Each participant has to hold an input lecture.

The seminar is limited to 20 people. There will be a waiting list.

Please note:
Around 4-5 meetings will take place outside ETH Hönggerberg and some at Graphische Sammlung ETH Zürich in the main building. Time for travel before and after the meetings is therefore necessary.

052-0835-21L Summer School: Transects Through Alpine Water Landscapes (ETH-EPFL)
For MSC ARCH students and Doctoral students.

Abstract
Through field expeditions, keynote lecture, discussion, workshops, and exchanges with experts, participants will contribute to the production of a synthetic ‘transect’ across a continuous water landscape. The transect operates as a record of relations along a set path, from the Aletsch glacier to the Rhone valley floor, revealing larger territorial logics.

Objective
Learning objectives include the acquisition of foundational conceptual knowledge related to (1) landscape, planning, and systemic design issues linked to water in the Alps, and (2) broader trans-disciplinary challenges facing water landscapes (climate change, agriculture, energy, urban drainage). Participants will also develop observational and analytical skills alongside the methodological tools of field research from architecture, landscape architecture, archaeology, geology, and surveying. The final outcome will be the production of individual field diaries and a synthetic transect discussed through formal presentation and critique.

Content
Water is a finite resource that has increasingly become a major geopolitical issue. In the European context, the Alps hold a strategic position as the ‘water tower of Europe’. Industrialization and urbanization apply significant pressure onto the water ecosystems of alpine valleys. Modifications to the flow of rivers can significantly impact downstream regions, across very extensive areas. Thus, concerted landscape management and urban planning is essential, especially as natural and man-made water systems are affected by climate change. The transect along the Massa river, from the Aletsch glacier to the Rhone valley floor, presents archetypal water management issues and opportunities. The transect is thought of as an autonomous territorial entity, which could be used as an abstract model for future systemic planning.

Fieldwork will be employed as a form of direct engagement with the landscape to document key infrastructure, such as irrigation channels, dams, and drainage systems. It will highlight specific urbanization processes and their associated ecosystem services (water retention, habitat provision, recreation). The objective is to develop a spatial, empirical, and material understanding of the landscape.

Lecture notes
Teaching involves 4 expedition days, 1 production day, and 1 final critique day. Doctoral students with relevant expertise will lead field research on expedition days, supplemented by keynote lectures by invited guest experts. Workshops will take place on site and in the seminar room at Villa Cassel. Professors from ETH and EPFL will take part in the final day of critique.

Location: Villa Cassel, 3987 Riederalp, Kanton Wallis
Duration: 6 days
Dates: 16-21 August, 2021

Participation fees cover accommodation including full board at Villa Cassel. Master students (ETH/EPFL): CHF 100; Doctoral students (ETH/EPFL): CHF 250; Doctoral/master students (external university): CHF 500. All participants are required to take part in the full 6-day summer school (2 ECTS); mountain hiking is required.

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving not assessed

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

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking not assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

052-0851-21L Topical Questions in History and Theory of Architecture: Gendering History. Women Travellers

Abstract
This course will take the form of reading seminars in which we examine women’s travel writings of the 18th and 19th centuries for their commentary on the designed environment. While architectural histories often focus on male-dominated processes of design and production, this seminar sets out to discover architecture’s past as seen through the eyes of female travellers.

Objective
Students will gain experience in different forms of reading primary sources (close and distant) and in placing these into an appropriate context. We will explore methodological approaches linking literary analysis to lived architectural experience, expanding the canon of our discipline as we include the view of women into our understanding of 18th and 19th-century architecture. Students will be familiarized with feminist approaches, intersectionality, and marginal historiography.

Primary readings are accompanied by secondary texts on feminist and intersectional methods and embedded into practical exercises. Students will prepare short presentations, engage in reading and sketching exercises, and undertake their own ficto-descriptive writing, expanding their critical writing skills.

Prerequisites / notice
This course is aimed at students from the 5th semester onwards. It will require a set amount of reading and sessions will include intensive discussion and practical exercises, so consistent attendance is very important.
same time.

Abstract
Works in the integrated discipline art and architectural history evolve in close connection with projects in design. Textual and creative works are possible. The length of the text or the extent of the creative project will be decided upon individually.

Objective
We expect that students pursue their examination of the design process independently and in an original manner or that they develop a related theme from the perspective of the history of art and architecture. The work should be part of the design process and interact with it formally and in regard to content.

Content
Works in the integrated discipline art and architectural history evolve in close connection with projects in design. Textual and creative works are possible. The length of the text or the extent of the creative project will be decided upon individually.

052-0853-21L Architecture Beyond the Studio: Reflecting the Social and Cultural Dimensions of Design Proposals
This course is offered until end of spring 2023 semester.

Abstract
"Architecture beyond the studio" is a seminar with the aim to reflect and rethink the formal and spatial aspects of the students’ own design projects from the perspective of the Humanities and Social Sciences (HSS). Literature from the HSS is researched individually, related to the design projects in the form of a paper and presented jointly in an exhibition.

Objective
In this seminar students learn to critically reflect their practice as architects from the perspective of the humanities and social sciences (HSS). As object for these reflections serves one of the students’ own design projects. This can be an architectural project they have designed at a chair for architecture and design, an architectural practice or independently.

Content
Currently, the discipline of architecture is undergoing substantial change. Political and social aspects are again becoming more important within the profession of architecture. In the 1980s and 1990s architects legitimized their designs by recurring to their artistic abilities and individual ingenuity. Today, however, practicing architects cannot escape the social and political responsibility that comes with the design of architectural buildings. An increasing number of public as well as private developers expect architects to include considerations about the social and cultural live of prospective inhabitants in their architectural designs.

Prerequisites / notice
Against this background, the seminar "Architecture beyond the Studio" bridges the gap between architectural design and the Humanities and Social Sciences (HSS). Supported by two lecturers – with backgrounds in architecture and the social sciences – the students develop texts in which they critically reflect on spatial aspects in one of their own design projects from the perspective of the HSS.

The aim of this seminar is to enable students to better understand social, political and/or economic dimensions of spatial aspects in their architectural designs. The students’ tasks include reflexive and analytical writing, the presentation and discussion of these reflections, literature research and the production of a final text, in which they summarize their most important findings and define a theoretical position that could guide their future work as designers.

During the semester the seminar will be held as elective course (4 ECTS), including group-work, input by the tutors and individual feedback sessions. Additionally, this seminar contains two one-week-long writing workshops, which will be offered as focus work (6 ECTS) during the semester break. Next to a paper, the outcomes of this seminar will be presented in an exhibition taking place at the beginning of the following semester.

Prerequisites / notice
As the number of participants is limited, interested students are asked to send an A4 page including one image and/or one plan of a previous design project as well as 3-4 sentences describing the aspect of the design project the student wants to investigate and reflect on during this seminar. In order to register for the seminar, students have to send this document to both of the tutors of this course.

Students enrolling in this elective course are required to additionally enroll in the Focus-Work at the gta at the Chair of Prof. Philip Ursprung (063-0852-21). By successfully completing the whole seminar students receive 4 ECTS for the elective course and 6 ECTS for the focus work.

052-0855-21L Summer School: On the Threshold - Guidebooks and Visions of Rome

Abstract
The summer school explores the mediated territories between the city, its guidebook and the traveller. By adopting a selection of itineraries established by past and present guidebooks, students investigate the thresholds of Rome, between the built city and its tourists.
### Objective
By the end of the five days every group will have worked on a series of different building elements for each guide, so that by the end of the week about 25 units will be produced. As a collective critical guidebook of Rome, the units designed and written by the students will be presented in a final, one-day public exhibition and lecture on the last day. The instructors will follow the entire workflow, leading the visits, revisiting and checking the design outcomes, and coordinating the production phase.

The general aim of the week is not to present a linear or comprehensive history of the tourist guidebook, but rather to foster and implement a discourse around topics directly informed by the experience of tourism, such as everyday life, heritage, city planning, and artistic production. To this end, students will engage in in-depth analyses of specific historical periods through both scientific-synthetic and artistic-creative methods, and on a more comprehensive understandings around how to read a city, and how to critically employ a travel book. The itineraries are based on guidebooks stretching over a wide timeframe. Hence, by observing the contemporary phenomenon of tourism through a mass-social platform such as TripAdvisor, the programme introduces the topic of the Summer School from a familiar perspective, moving towards more historical and theoretical approaches as the week progresses.

The Summer School is planned for 15 international participants, ideally Master students or early career researchers, coming from different disciplines and curricula, such as architecture, applied arts, art history, literature, philosophy, sociology, photography, city studies and media studies. Use of personal laptops/tablets is expected. Students and tutors will stay at the magnificent Villa Maraini, the historical seat of the Istituto Svizzero. The fee will be 300 euro comprehensive of lunch (6 days).

This summer school is addressed to students from the 5th semester upwards.


### Content
We will dedicate one day to each of the five guidebooks, following an itinerary inspired by each publication. Details of each day’s visit will be determined and planned before the beginning of the week. By following a 'pre-determined' path, five visits through the city will be conducted during the morning. We will move and stop to linger along physical thresholds determined by various urban elements, such as monuments and buildings, observing the built environment as well as the ways in which tourists, visitors and citizens look at, interact with, admire, photograph and film places. Hence the relationship between public and private, between individual experience and collective knowledge will be investigated, documented and analyzed.

### Prerequisites / notice
This summer school is addressed to students from the 5th semester upwards.

2021-07-25 to 08.01 2021 at Istituto Svizzero Rome

### Landscape and Urban Studies

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>you participate in the curatorial work of the thematic exhibition &quot;Life Without Buildings&quot;. The tutors are Adam Szymczyk (curator and artistic director of documenta 14), Fredi Fischli and Niels Olsen (gta exhibitions). Throughout the semester you are introduced to numerous artists, architects and authors visiting the course.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>In this elective course you actively engage in exhibition making and you reflect on methods of curating, while focusing on &quot;exhibiting architecture&quot;.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>A reading list will be provided.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Contribution / A project realized individually or as a team for the exhibition.</td>
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</table>

### Serendipity: Sourced Waters

**Number of participants limited to 16 (due to technical equipment).**

**Course language:** English or/and German

**Abstract**

The next stop in our investigation of Zurich's water infrastructure is the spring water. Through acoustic and visual field recordings the students find a variety of ways to represent one starting point of the urban system.

**Objective**

Through the use of multimedia tools, this course will reflect on the contemporary use and perception of landscape. Analogue photography and audio recordings will be represent the core body of the work.

**Content**

Attention: The final inscription will take place on the first course date, everybody is treated the same.

After having investigated the lake water catchment and treatment plant Zürich-Lengg and Zurich’s water storage chambers the reservoirs we will put our attention with the course «Sourced Waters» on another starting point of the water infrastructure of Zürich: to the spring water source.

Far from Zurich, the glacier shaped landscape allows an usual access to lower water-carrying layers. After ten years enclosed between gravel and rock, the waters turns up in the wall of an ancient tunnel. After having investigated the lake water catchment and treatment plant Zürich-Lengg and Zurich’s water storage chambers the reservoirs we will put our attention with the course «Sourced Waters» on another starting point of the water infrastructure of Zürich: to the spring water source.

Following the fieldwork, students will work on an audiovisual composition in the analogue PhotoLab and in the AudioVisual-Lab at the ETH Hönggerberg.

Notes: The course will be limited to 16 students. Participation on the following events of the course is mandatory: Introduction, Workshop, Mid- and Final Presentations. The Chair will provide some financial support (costs for production), possible additional costs (transportation, overnight stay, food and drinks) are asked to be paid by the participants. Basic trekking experience and outdoor clothing is required.

**Prerequisites / notice**

23.09.2021: Introduction and final inscription!

02.-03.10.2021: Weekend workshop, all day, in Zurich (mandatory) [if the current state of the pandemic allows]

CORONA: Due to the pandemic and the current situation during the semester, the course may be adjusted. It is unclear at the moment whether the workshop can take place as planned. Likewise, the physical work in the laboratories will have to be adapted selectively, depending on the rules and regulations.

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>052-0715-21L</td>
<td>Topology: Deep Poly W</td>
<td>W</td>
<td>2 credits</td>
<td>2U</td>
<td>M. Kaufmann</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Topological analysis through point cloud modelling. The underground is an infrastructure in more than one way. Below the ground, various facilities enable the connectivity of today's urban life. The topological approach using point cloud modelling reveals the seemingly invisible networks.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>You will learn to use 3D point cloud technology in order to analyze complex urban landscape and develop new ways of representing these intertwined spaces.</td>
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**Data:** 14.12.2021 12:41

**Autumn Semester 2021**
A course booklet will be provided at the first introductory meeting. For further information, please see: https://giot.arch.ethz.ch/courses/elective-courses/deep-poly

**Objective**

The elective introduces to the subject and complexity of the urbanized landscape and teaches the critical engagement with the challenges and potentials of current tendencies in Landscape Architecture. On the basis of a concrete study area, students examine the large-scale processes of reuse, reform and reinterpretation of metropolitan landscapes in Europe and develop new approaches and strategies on various scales. They become familiar with GIS as an analytical tool, model building as a design methodology and the representation of landscape through plans. They develop a project based on the perception of place, knowledge of landscape-architectonic typologies and conception of public space. The design process is accompanied by workshops, lectures, excursions, critiques and a workbook.

**Content**

The elective deals with current transformation processes of metropolitan landscapes in Europe and introduces landscape architecture design on a territorial scale. On the basis of cartographic analysis and field trips, students will develop concrete strategies for the urban landscape of the Grand Paris.

**Lecture notes**

A course booklet will be provided at the first introductory meeting. For further information, please see: https://giot.arch.ethz.ch/courses/elective-courses/deep-poly

**Literature**

A course booklet will be provided at the introduction. Furthermore, a semester apparat will be available to the students at the ILA Library.

**Prerequisites / notice**

Workshop Weekend: 9th/10th October

The course space is ETH Hönggerberg, LVML H40.8.

The assignment will be developed in groups of two.

**Language of instruction is English; assistance in English or German.**

**052-0717-21L**

**Territory of the City: Paris**

*Number of participants limited to 12.*

*Enrolment in agreement with the lecturer only.*

**Sociology: African Urbanities - A Research Seminar**

*The number of participants is limited to 40.*

**Content**

Africa is an increasingly urban continent. How is this urbanity being produced? What form is it taking? And how is it being represented?

**Objective**

Participants will be expected to engage actively in:

- identifying and presenting creative representations of African urbanity
- gaining insights into the variety of urban forms and practices in Africa
- acquiring new skills in hosting and interviewing experts
- strengthening ability to read, present and debate academic texts
- making connections between scholarly findings and artistic productions

**Prerequisites / notice**

A workbook with texts and background information is available for purchase (CHF 20.-). A digital version is also available for free.

**Sociology: African Urbanities - A Research Seminar**

*The number of participants is limited to 40.*

**Abstract**

This research seminar will explore the multiple and varied facets of African urbanity today.

**Objective**

Participants will be expected to engage actively in:

- hosting and curating discussions with guests
- debating and discussing scholarly texts
- identifying and presenting creative representations of African urbanity

**Content**

This course will unpack the range and variety of contemporary African urbanity. In doing so it will engage with both urban form and practices currently emerging, seeking to capture both their local manifestations as well as their regional, and global relevance. We will challenge the various cliché snapshots of African urbanity, as defined by a lack of infrastructure, a shortage of resources, or the informal slum. Instead, we will seek to produce a more complex portrait of African urbanity today, moving away from the city and its centre as the sole locus of urban activity, to consider the role of extended urbanisation, trans-local networks and the digital arena in shaping new urbanities.

**Literature**

The assignment will be developed in groups of two.

**Language of instruction is English; assistance in English or German.**

**052-0723-21L**

**Sociology: African Urbanities - A Research Seminar**

*The number of participants is limited to 40.*

**W** 2 credits

**S** 2G 2S

**A. Hertzog-Fraser; N. Bathla; C. Schmid**

**Abstract**

Africa is an increasingly urban continent. How is this urbanity being produced? What form is it taking? And how is it being represented?

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Participants will be expected to engage actively in:

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**Notice**

Each session will be structured a main reading and a presentation and discussion with our guest expert. In addition to this, students will be expected to present current representations of the topic under debate. Alongside these conversations, we will read our way through a rich syllabus of both scientific articles, book chapters, and reviews. This will be complemented with an exploration of how art, film and fiction has shaped, and continues to shape current representations of urban Africa.
The course will be held in English. Participants must be able to read and speak English.

**052-0725-21L**

**Abstract**

In the turf war between quantitative and qualitative methods, we appear as mediators bridging the two sides. How can quantitative and qualitative methods complement each other rather than work in opposition?

We will encourage reflections on this by developing new forms of urban literacy integrating ethnographic research methods with quantitative data, filmmaking and other forms of digital media.

Objective

Through a combination of practical exercises in video and audio techniques in parallel with the study of seminal observation-driven texts, this course aims to equip students with the basic tools and core principles to create short but complex portraits of urban space. This semester, the focus falls on the green spaces of Zürich, looking at its trees, green corridors, heat islands, and atmospheric conditions.

This approach will be applied to experiments in the audio/visualization of quantitative data and the contextualization of qualitative data that in turn inform quantitative outputs. Through various audiovisual experiments, students will collectively speculate on ways to marry the various forms of research methods that traditionally do not intersect, creating mosaics of experimental research forms, manifested through film and audio.

Using widely available recording tools and editing software, students will turn their fieldwork into short video or audio works of about 3-5 minutes.

Content

The course will compose of lectures, practical crash courses in media use and storytelling, and fieldwork sessions. The course will be a laboratory in the creation of short media works that aim to inform the architectural design process, working between the city and the studio in ONA. Students will be expected to complete all required work within the hours that the elective meets, with few requirements outside of the class hours.

**Literature**

Seminal texts include:

- ‘Cross-Cultural Filmmaking’ (Barbash, Castaing-Taylor)
- ‘Acoustic Territories’ (LaBelle)
- ‘Ethnography: Principles in Practice’ (Hammersley, Atkinson)
- ‘Thick Description: Toward an Interpretive Theory of Culture’ (Geertz)

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork
- Negotiation

Domain D - Personal Competencies

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

**063-0761-21L**

**Abstract**

Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.

**Objective**

Students gain an insight into the integrated disciplines of design in architecture together with landscape architecture.

Content

Design concepts ranging from architectural objects to urban planning are developed together with the discipline of landscape architecture. Dependent on the task at hand different themes are investigated. The goal of the integrated discipline is to develop design solutions of a specific topic in landscape architecture, which have to be incorporated into the overall design submission.

**052-0735-21L**

**Abstract**

We design models for the future of the Berlin-Brandenburg metropolitan region. We try to think about the future of the city explicitly from the perspective of the landscape. An analysis on two levels (pedestrian perspective: field trips as well as data and plan analyzes: GIS) lays the foundation for the design discussion in the second part of the course.

**Objective**

The students examine the metropolitan region of Berlin-Brandenburg and develop new approaches and strategies for the future of the urban landscape on different scales. They will familiarize themselves with methods of perception from the perspective of pedestrians, with GIS as an analysis tool, model making as a design method, and landscape architectural plan representation. Current issues with which urban landscapes will be confronted in the future (climate, densification, mobility, etc.) are addressed. The design process is accompanied by workshops, lectures, excursions, reviews, and a workbook.
Based on an analysis of the urban landscape, the students develop models for the future of the Berlin-Brandenburg metropolitan region. The Winter School is organized and carried out together with the University of Applied Sciences Potsdam. Close cooperation between the students of both universities is sought.

The metropolitan region of Berlin-Brandenburg is expected to grow rapidly over the next few decades. Similar to other metropolitan regions in Europe, the background of current issues (land consumption, mobility, urban climate, etc.) the question is of how the development should take place.

As a starting point for the considerations, we suggest a change of perspective. The strategies and models should not be developed based on the city, but rather from the surrounding landscape. At the beginning of the Winter School, there is an intensive preoccupation with the urbanized landscape of the Großstadt region. Based on an in-depth understanding of the conditions and genesis of undeveloped space, it is important to identify potential and explore room for maneuver. On this basis, the urban landscape is to be further considered holistically.

The students work in groups of two (ETH/FHP) and focus on different Perimeters. The work process is structured in four phases:
I: research and analysis,
II: program and design,
III: development and communication,
IV: synthesis.
In the last step, the different results become one "overall picture" and theses derived. The results are then publicly debated. Communication via exhibitions, newspapers, etc.

The Winter School will take place in Berlin. Between 30.01.22 and 14.02.22.

### Technology in Architecture

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>101-0587-00L</td>
<td>Workshop on Sustainable Building Certification</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>D. Kellenberger</td>
</tr>
</tbody>
</table>

**Number of participants limited to 25**

**Abstract**

Building labels are used to certify buildings and neighbourhoods in terms of sustainability. Many different labels have been developed and can be used in Switzerland (LEED, DGNB, SNBS, Minergerie, 2000-Watt-Sites). In this course the differences between the certification labels and its application on 3 emblematic case study buildings will be discussed.

**Objective**

After this course, the students are able to understand and use the different certification labels. They have a clear view of what the labels take into consideration and what they don't.

**Content**

Three buildings case study will be presented.

**Literature**

All documents for certification labels as well as detailed plans of the buildings will be available for the students.

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>151-8015-00L</td>
<td>Moisture Transport in Porous Media</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>J. Carmeliet, L. Fei, J. Huang, J. Zhao</td>
</tr>
</tbody>
</table>

**Abstract**

Moisture transport and related degradation processes in porous materials; experimental determination of moisture transport properties; theory and application of pore network model for two-phase transport in porous media; flow in cracked and deformable porous media.

**Objective**

- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Knowledge of pore network model and application to two-phase invasion percolation simulation
- Application of knowledge to moisture transport in cracked materials and flow in deformable porous media

**Content**

1. Introduction
   - Moisture damage: problem statement, durability
   - Applications: building materials, soil science, geoscience
2. Moisture transport: theory and application
   - Description of moisture transport
   - Determination of moisture transport properties
   - Liquid transport in cracked materials, flow and transport in deformable porous media
3. Pore network model: theory and application
   - Single- and two-phase pore network model: quasi-static and dynamic
   - Exercise on quasi-static two-phase pore network model: invasion pattern, capillary pressure curve
   - Application of pore network model in two-phase transport

**Lecture notes**

Handouts, supporting material and exercises are provided online via Moodle.

**Literature**

All material is provided online via Moodle.
Historical and Systematic Aspects of Acoustic Design in Architecture (HS) 2 credits 2G J. Strauss

Prerequisites / notice
Introductory event: 24.9., 14:00 h, HIB Open space E-Level. Participation in the introductory event is a prerequisite for this course! Structure (Lectures, field work, final presentation) will be communicated in time.

ZoomLink: https://ethz.zoom.us/j/66588100789

This course is offered in cooperation with the chairs of Gramazio/Kohler and Delbeke. It is offered the last time in HS21.

Building Process: Realization (HS) 2 credits 2G G. Habert, D. Kaushal

Abstract
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. In 2016, other political bodies made these changes more difficult to predict. 

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification

Main issues:
- Operation energy at building, urban and national scale
- Sustainability, energy, and density questions
- Embodied energy for developing and developed world
- Synthesis: Transition to sustainable development

Content
The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development

Lecture notes
All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

This course (ends with «00L») can only be passed once!

Building Process: Realization (HS) 2 credits 2G M. Eglin

Abstract
Visits to construction sites and interdisciplinary lectures on the topics of communication, complexity, landscape and investment are the main focus of the workshop. In addition, the term process is to be depicted by means of visits to manufacturers of construction components.

Objective
The main focus of the diploma elective subject is in showing the building process by means of current examples of urban design with architectural relevance. The Chair views itself as the facilitator between those involved in construction and students. Active participation is a prerequisite.

Content
The main focus of the diploma elective subject is in showing the building process by means of current examples of urban design with architectural relevance. Visits to construction sites and interdisciplinary lectures on the topics of communication, complexity, landscape and investment are the main focus of the workshop. In addition, the term process is to be depicted by means of visits to manufacturers of construction components. The Chair views itself as the facilitator between those involved in construction and students. Active participation is a prerequisite.

Lecture notes
The recordings of the lectures are available on the MAP under the link https://map.arch.ethz.ch (book symbol at the top right).

Literature
https://map.arch.ethz.ch

This course is limited to 40 students. Enrolment is only possible in agreement with the lecturer (eglin@arch.ethz.ch).

This course (ends with «00L») can only be passed once!
Please check this before signing up.

Autumn Semester 2021
Abstract
Selected texts from the history and theory of architecture are discussed. The focus is on the design principles of exemplary buildings for speech and music and their historical and systematic significance.
A visit to the music studio will give you the opportunity to have your own listening experience and emphasize the importance of spatial listening for the perception of architecture.

Objective
The examination of the acoustic architectural design is intended to make the design potential of acoustics clear. The sensitization for the everyday phenomena of the acoustic impression of the room as well as the orientation and localization of sound sources in the room play a prominent role. The knowledge derived from history should provide information about the success and failure of different concepts for buildings for music and speech.

Content
The starting point for the historical consideration of the acoustic architectural design is the imagination of the harmony of the spheres: the Pythagorean-Babylonian cosmos is well-formed by proportions of whole numbers and elementary geometric figures. Mediated by Plato, Aristotle and the Stoa, the four Pythagorean mathematica (astronomy; geometry; music theory; algebra) appear as a medieval training course (quadrivium) in monasteries and thus also shape Leon Battista Alberti’s idea of a well-formedness. Does Vitruvius share this Pythagorean cosmos of ideas?
Reffering to Aristoxenus, Vitruvius uses a theory of harmony for the dimensioning of sound vases in theaters, which makes the audible criterion and thus stands in opposition to the ideality of purely mathematical pitch division through the proportions of whole numbers.
Connected with this turn towards the perceptible of the inner world, Vitruvius gives us a whole series of examples of acoustic design of architecture and uses the terms sound wave, sound beam, reflection, resonance and sound coloration.
The criticism of the theories of proportion, as produced in large numbers by Vitruvianism of the Renaissance, is essentially done by Claude Perrault, whose work also includes a contribution on sound and noises (Du bruit) and tries to transcend the music theory of Pythagorean origin.

The baroque author Athanasius Kircher dealt with the formation of analogies between the eye and the ear in his work “New Hall and Thon Art” and transferred the geometric representation of light rays by Galileo Galilei to sound rays. Based on the echo phenomenon, he succeeded in describing sound reflections, bundling and scattering, which today form the basis of room acoustic simulation programs.

The collaboration between Gottfried Semper, Otto Bückwald and Richard Wagner on the development of a festival theater for Wagner’s musical dramas has become an example of the acoustic design of architecture. An extraordinary performance space was created in Bayreuth, the diffuse orchestral sound of which contrasts sharply with the distinctness and clarity of the voices. Neither the architects nor Wagner had any room acoustic parameters available for planning; but after the final visual and acoustic votes, the composer and impresario was satisfied.

It was only with the experiments of Wallace Clement Sabine, published in the “Collected Papers on Acoustics”, that the reverberation time parameter was formed and used for the new “Boston Symphony Hall” to be built. Sabine has visited and listened to European concert halls in order to find an optimal space for symphonic music.

In addition to the structures for music and speech, the “soundscape” of cities and landscapes has recently established itself as a theme of sound ecology. As a follow-up to Murray Schafer’s “Tuning of the world”, a number of studies and designs have been carried out that are intended to enable acoustic comfort in all architecturally designed rooms.

Up until now, architecture has included building and room acoustics for special structures, but today it is being expanded significantly through electroacoustics. Today, buildings can be simulated and auralized from a 3D plan, not only through ambient and elevator sounds, but also through sound systems that create spatial impression, such as in the cinema. These auxiliary tools have already become indispensable for the acoustic planning of rooms.

Prerequisites
ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Semester</th>
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<tbody>
<tr>
<td>052-0627-21L</td>
<td>CAAD Theory: Digital Epic - Creative Writing for Architects</td>
<td>2</td>
<td>Autumn Semester 2021</td>
</tr>
<tr>
<td>052-0629-21L</td>
<td>CAAD Practice:</td>
<td>2</td>
<td>Autumn Semester 2021</td>
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<tr>
<td>063-0661-21L</td>
<td>Integrated Discipline HS21 in the Field of Technology in Architecture (ITA)</td>
<td>3</td>
<td>Autumn Semester 2021</td>
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</tbody>
</table>
Enrolling in this course is only possible on agreement with the lecturer and if you attend a design course (V-IX) at the same time.

Abstract
This part of the curriculum addresses design work in different areas of architecture and urbanism and integrates the knowledge acquired in previous years. It involves the active participation of specialists from the chairs of the institute ITA.

Objective
Understanding the importance of the ITA disciplines for architectural design and integration of structural thinking into the design process.

Content
This part of the curriculum addresses design work in different areas of architecture and urbanism and integrates the knowledge acquired in previous years. It involves the active participation of specialists from the chairs of the institute ITA.

052-0639-00L
Climate Responsive Architecture with Hive

Abstract
This Online course provides an introduction to climate-responsive design using the Hive tool and how to apply it in early building design stages. Hive allows architecture and building science students to understand the relation between architectural design, climate, comfort and energy. Hive is a plugin for the 3D modeling environment Rhino and its visual programming interface Grasshopper.

Objective
- Recall general principles of climate responsive design and examples of it.
- Utilize 3D building geometries to conduct simplified energy demand and supply simulations.
- Observe relevant physical principles and interactions between climate, energy and geometry.
- Implement passive and active concepts for Climate Responsive Design.
- Apply Hive for building design analysis and integrate it into own designs or in design courses.
- Identify and harness synergies and trade-offs between climate, energy and architectural design aspects.

Content
The course can be frequented individually, or as a prerequisite for other courses such as the master course Climate and Energy Systems 3 or architectural design studios.

Modules:
1. Course overview.
2. Introduction to climate responsive design.
3. Introduction to Rhino, Grasshopper and Hive.
4. Early solar analyses.
7. Real-world Applications and Examples.

This is a blended-learning self-paced ONLINE COURSE that can be started at any time.

Prerequisites / notice
A working Rhino 6 or 7 license is necessary.

Historic Building Archaeology and Conservation

Number Title Type ECTS Hours Lecturers
063-0961-21L Integrated Discipline HS21 in the Field Historic Building Research and Conservation (IDB) W 3 credits 2A Lecturers

Abstract
The formal framework needs to be discussed with the staff members.

Objective
A study in building research and preservation of building heritage with a clear topic.

052-0913-21L Preservation: Communicate & Exhibit

Number of participants limited to 40.

Abstract
This elective course discusses current as well as historical practices and theories of preservation. Under the title "Communicate & Exhibit", the focus in the fall semester of 2021 is on forward-looking positions on "Building in the Existing Building Stock" and how these are communicated to the public by preservation experts, architects, and curators.

Objective
This course provides students with insight into the most important theories and practices of historic preservation and ways of conveying and exhibiting them. Students can deepen their understanding of the subject and discuss issues in a group by examining a topic of their own choice.

Content
Current strategies of "building in the existing fabric" are backed by various historical theories and practices of preservation. But which architects follow - explicitly or implicitly - which theory? How do these points of view evolve through the activities of different actors in their preservation and building activities, what forms of sufficiency have been and are being practiced? What "first works" are worth showing that introduce significant architectural oeuvres as building within the existing built fabric? In the fall semester of 2021, we will explore influential approaches to preservation and examine narratives associated with them, such as resource allocation, change of use, and "modernisation". We will also analyse, discuss, and question their public communication. The insights gained will flow into the development of curatorial concepts, which will be applied and tested on the basis of a specific project site.
<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<td></td>
<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<td></td>
<td>Creative Thinking</td>
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<td>assessed</td>
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<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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**052-0911-21L Repair: Making Things Better**

W 2 credits 2S S. Langenberg

**Abstract**
The lifespan of objects is decreasing not only in product design but also in architecture due to complex constructions, use of materials that are difficult to dismantle, and industrial manufacturing processes. Repairability is becoming less of a concern - replacement seems to be the norm. We need to rethink the way we build, starting already during the planning phase.

**Objective**
Traditional topics of preservation are combined with implementations of contemporary repair and FAB initiatives to raise awareness for a sustainable thinking and action. Students will learn both traditional and digital methods as well as the basic constructive and material criteria for repair. The objective is not only the hands-on repair of an object but especially the theoretical transfer to architecture.

**Content**
The elective course will discuss and examine the reparability of products and constructions. Based on a broken object of their choice, each student will first identify its defects and the reasons. Subsequently, they will develop a repair concept and carry it out under expert guidance or with the aid of digital fabrication processes. The objective is not only to restore the object to a working condition, but also to improve it through repair - if and where possible.
Literature

Abel van, Bas, Roel Klaassen, Lucas Evers und Peter Troxler (Hg.), Open Design Now, Amsterdam 2011.

Auerbach, Lisa Anne, Don’t do it yourself!, Studienhefte Problemorientiertes Design 2, Hamburg 2013.

Baier, Andrea u. a. (Hg.), Die Welt reparieren, Bielefeld 2016.

Baier, Andrea u. a., Stadt der Commonisten, Bielefeld 2013.

Baumeister, Reparaturkultur – Vom Wert der Dinge, Heft 8/2020.


Braungart, Michael und William McDonough, Cradle to Cradle, München 2014.

Fastermann, Petra, 3D-Drucken. Wie die generative Fertigungstechnik funktioniert, Berlin 2016.


Gewiese, Angela u. a., Recycling von Baureststoffen, Renningen 1994.

Gramazio, Fabio, Matthias Kohler und Silke Langenberg (Hg.), Fabricate: Negotiating Design and Making, Zürich 2014.

Grewe, Maria, Teilen, Reparieren, Mülltauchen, Bielefeld 2017.

Hassler, Uta (Hg.), Langfriststabilität: Beiträge zur langfristigen Dynamik der gebauten Umwelt, Zürich 2011.


Krebs, Stefan u. a., Kulturen des Reparierens, Bielefeld 2018.


Mclellan, Todd, Ganz schön zerlegt, Potsdam 2013.


Schmidt, Hartwig (Hg.), Das Konzept Reparatur. Ideal und Wirklichkeit (ICOMOS Hefte des Deutschen Nationalkomitees XXXII), München 2000.

Schridde, Stefan, Murks? Nein danke! Was wir tun können, damit die Dinge besser werden, München 2014.


Sommer, Bernd und Harald Welzer, Transformationsdesign, München 2014.


Thun-Hohenstein, Christoph (Hg.), handWERK. Tradiertes Können in der digitalen Welt, Wien 2016.

Walter-Herrmann, Julia und Corinne Büchting (Hg.), FabLab: Of Machines, Makers and Inventors. Bielefeld 2014.


Prerequisites / notice

ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

052-0915-21L An Example-Based Introduction into Building Archaeology

W 2 credits 2V L. Vandenabeele

This course is offered until end of HS22.

Abstract

An introduction to the scope, methodology, theoretical and practical developments of Building Archaeology (historische Bauforschung) based on a large-scale ongoing project conducted by the institute IDB under the project lead of the lecturer himself.

Objective

Introduce students to the current methodology and scope of Building Archaeology.

Content

This lecture will introduce students to the scope and methodology of Building Archaeology (historische Bauforschung). It will be given by the project leader of the ongoing project "Building history of the Basilica of St Anthony, Padua". Based on that project as a case study, but including other examples, the lecture will show how to formulate hypotheses in a BA project, how to develop a strategy of investigation, how to proceed methodologically and technologically. The course will cover surveying methods like laser scanning and 3D modeling (e.g. 3D printing, BIM for heritage), terrestrial and drone-based photogrammetry (structure from motion) and thermal imaging, as well as dating techniques like radiocarbon (14C), dendrochronology, mensiochronology (dating by statistical evaluation of brick sizes) and archival research. It will present the main project in parallel to the ongoing investigations, giving the students a unique opportunity to participate in the strategy, progress and preliminary results of an actual research project. Furthermore, the stage will be opened for an outlook on other projects, hence providing a broad overview of the field of BA and its recent developments. As the monument considered contains important historical structures from the 13th to the 18th centuries, this lecture will also offer a practical insight into Construction History.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

►► Focus Works

see Architecture MSc "Focus Work"

► Seminar Weeks

Number       Title                                      Type  ECTS  Hours  Lecturers
051-0911-21L Seminar Week Autumn Semester 2021     W     2 credits  3A     Lecturers

Abstract
The seminar week is obligatory for students of all semesters. There are many and varied study contents.

Objective
The students will be enabled to discuss narrowly formulated factual questions in small groups and in direct contact with the professors.

► GESS Science in Perspective

►► Science in Perspective

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-ARCH.

►► Language Courses

see GESS Science in Perspective: Language Courses ETH/UZH

Architecture Bachelor - Key for Type

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

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

ECTS European Credit Transfer and Accumulation System

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

## Core Courses

### Field of History and Theory of Architecture

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>063-0801-00L</td>
<td>History of Art and Architecture VII:</td>
<td>W</td>
<td>2</td>
<td>2V</td>
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<tr>
<td></td>
<td>Imagining History and Inventing Architecture</td>
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<td>This core course ending with «00L» can only be passed once! Please check before signing up.</td>
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<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This class studies Antiquity and the Middle Ages through their reception since the Renaissance. We will investigate the role of history for architects then and now by analyzing how architecture has been defined in relationship to the past. The course includes short critical reading and writing assignments (in coordination with studio deadlines).</td>
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<td></td>
<td>Deepen basic knowledge, improve ability to critically analyze architectural history texts, develop humanities-based reasoning and argument skills, especially persuasive writing</td>
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<td>Content</td>
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<td>In the Renaissance, the practice of architecture fundamentally transformed into the design-based discipline it is now largely assumed to be. Both then and especially in nineteenth- and twentieth-century architectural history, this change was understood in opposition to “good” ancient and “bad” medieval models. This course investigates Antiquity and the Middle Ages as variously fashioned in the mind of the architect and the architectural historian. How does our understanding of these periods inform our thinking about the use of history for the contemporary architect?</td>
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<td>This course is a combination lecture, writing, and discussion class: one brief text per week will be read at home and discussed in the course meeting. Short critical writing assignments will be assigned in the first half of the semester, and the final assignment is a short paper due during the January exam period. Written assignments will be scheduled to accommodate studio deadlines, and may be completed in English, German, French, or Italian. Active in-class participation is required.</td>
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<td>Literature</td>
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<td>Taught competencies</td>
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<td>Domain A - Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Domain B - Method-specific Competencies</td>
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<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Project Management</td>
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<td>Domain C - Social Competencies</td>
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<tr>
<td></td>
<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Domain D - Personal Competencies</td>
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<td>Adaptability and Flexibility</td>
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| 063-0803-00L | History and Theory in Architecture IX (Ursprung) | W    | 1    | 1V    | P. Ursprung |
|              | This core course ending with «00L» can only be passed once! Please check before signing up. |      |      |       |           |
| Abstract     | Out of the Crisis: Architecture in Times of Disease: Each lecture will be structured by an input by the professor and guests and followed by a discussion with all participants. |      |      |       |           |
| Objective    | Awareness of the role of the immediate present on architectural discourse. Knowledge of contemporary practices and discourses. |      |      |       |           |
| Content      | Out of the Crisis: Architecture in Times of Disease Which lessons can be drawn for architecture from the pandemic? Will there be a back to normal? How did concepts of space and time change? How can architecture education react? |      |      |       |           |
|              | Out of the Crisis: Architecture in Times of Disease: The lecture will pose questions rather than offer answers. Each lecture will be structured by an input by the professor and guests and followed by a discussion with all participants. |      |      |       |           |

| 063-0803-01L | History and Theory in Architecture IX (Avermaete) | W    | 1    | 1V    | T. Avermaete, H. Teerds |
|              | This core course ending with «01L» can only be passed once! Please check this before signing up. |      |      |       |           |
| Abstract     | This survey course offers an introduction to urban theory for students of architecture and urban design, by exploring the past and current discourses on cities and urban development. |      |      |       |           |
### Objective
It is often said that we live in an ‘urban age’: cities are the most common habitat for the inhabitants of the world, today. Moreover, while more than half the global population lives in cities according to the reports of the UN, it is expected that within the next few decades this amount will increase to two-thirds. This ‘urban’ condition, however, cannot be generalized. Within the term ‘city’ a broad range of different urban conditions are taken together: from metropolises to suburban neighborhoods, and from shrinking (old industrial) cities to the new cities that prosper under the condition of globalisation. Nevertheless, because of the increase of the urbanized environments, the development of cities forms the topic of discussion among a wide range of people. Urban developments do concern politicians, economists, anthropologists, philosophers, citizens and activists, developers and designers. In turn, the urban realm has provoked theorists, citizens, politicians, artists and designers to think and write about its form and functioning, appearance and structure. The discourse regarding the current growth of cities has a long pedigree in history, going back to the establishment of Greek and Roman city-states. In turn, urban planners have made valuable contributions to these discussions, in writings and in actual urban design projects and proposals.

This survey course aims to offer an introduction to urban theory for students of architecture and urban design, by exploring the past and present discourses on cities and urban development. By investigating a range of topics, from politics to poverty, and from modernization to commodification, it aims to show how urban and architectural design are related to theory. The aim of the course is to challenge the question how architects and urban designers can have an influence on urban development. With this question, also students are urged to reflect upon their own position regarding architectural interventions in the urban fabric.

This course aims to offer a survey of the history and current state of urban theory for students of urban design and architecture. Weekly, one-hour lectures address one particular topic at a time (e.g. politics, public space, capital). In each lecture, this theme is investigated through three case-studies (either of particular cities or seminal contributions by theorists or designers) that highlight crucial moments in the history and developments of cities. At the same time, the case studies will be structured so as to bridge between urban theories and concrete urban situations, design reflections and political ambitions. This will help convey to students the historical pedigree of current discourses on cities, whether simultaneously gain insight the role of designers in respect to the chosen topic. Students will prepare the meetings by reading fragments from core texts on the foreground.

### Content

<table>
<thead>
<tr>
<th>Lecture</th>
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<td>Lecture 01</td>
<td>Introduction</td>
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<td>Lecture 02</td>
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<td>Lecture 10</td>
<td>Urban Form</td>
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### Literature
| Taught competencies | Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Taught competencies | Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Taught competencies | Domain C - Social Competencies         | Communication          | assessed |
| Taught competencies |                                     | Leadership and Responsibility | assessed |
| Taught competencies |                                      | Self-presentation and Social Influence | assessed |
| Taught competencies |                                      | Sensitivity to Diversity | assessed |
| Taught competencies |                                      | Negotiation             | assessed |
| Taught competencies | Domain D - Personal Competencies      | Critical Thinking       | assessed |
| Taught competencies |                                      | Integrity and Work Ethics | assessed |
| Taught competencies |                                      | Self-awareness and Self-reflection | assessed |

### Prerequisites / notice

**063-0803-02L**

H
tory and Theory of Architecture IX (Gnehm)

**W** 1 credit 1V M. Gnehm

*The course languages are German and English.*

This core course (ends with +02L+) can only be passed once! Please check this before signing up.

**Abstract**

Between Cosmos and Chaos: Gottfried Semper’s Theory of Architecture

**Objective**

Knowledge of Semper’s theory and practice in the disciplinary context of nineteenth-century historicism and present-day architectural discourse.

**Content**

The seductiveness of Semper’s theory of architecture lies not least in the fact that he exploded world art histories popularized around the mid-nineteenth century through multifarious disciplinary borrowings ranging from anthropology to aesthetics and including natural sciences and linguistics, physiology and psychology, art and industry. This parallels his linking the smallest object and detail to the largest monumental building and his addressing philosophical questions centred around architecture such as those of the relation between nature and culture, the universal and the local, the material and the immaterial, body and soul, image and language, art and interpretation. In doing so, his global scope provokes political questions regarding the relation of identity and foreignness, of the West to the rest of the world.

**Prerequisites / notice**

Please note, this is a core course and it can only be passed once during the curriculum. Please check before enrolling!

**063-0313-21L**

History of Art and Architecture V: Caractère (Character)

**W** 1 credit 1V M. Delbeke, S. de Jong

*This course is full. Please do not enroll after 9.9.2021. Thank you.*

**Abstract**

This course is a reading class in which the architectural category of ‘caractère’ or character - a key concept in the 18th century but of great relevance until today - will be examined by a close reading of several key texts, from the late 1700s up until today. Independent reading and vivid discussion in class make up this course’s character.

**Objective**

Deepen basic knowledge, improve ability to critically read and analyze texts of architectural theory, and understand shifts in architectural thinking.

**Content**

‘Caractère’ or character is not only a quality applied to human beings. It is also a category of architectural discourse, developed in the 18th century when architects and theorists were seeking new ways to talk about and judge buildings, pushing architectural discourse beyond Vitruvian categories to which it had been tied for centuries before. This reading class will closely examine key texts that discuss the phenomenon of a building’s ‘character’ from the 1700s up until today. The weekly assigned texts (in the original French, English or German) will be read at home and then discussed in class. Independent reading and vivid participation in class are a fundamental prerequisite. In addition, there will be weekly written assignments, which all will be graded. A final written assignment at the end of the semester will be graded as well. To pass the course, students will have to read each assigned text, and hand in all written assignments on time.
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<tr>
<th>Number</th>
<th>Title</th>
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<td>063-0901-00L</td>
<td>Construction History: The Construction Site and Its Technology</td>
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<td>Cooperation and Teamwork</td>
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<td>063-0903-00L</td>
<td>Case Studies Construction History and Building Preservation (HS)</td>
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<td>Acquiring in-depth knowledge of construction history and building</td>
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<td>archeology by means of detailed study of selected historic monuments.</td>
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<td>The course will start with a multi-part classroom introduction,</td>
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<td>followed by field studies in small groups.</td>
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<td>The participants will gain in-depth knowledge on the methodology</td>
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<td>of building archeology by means of the documentation and</td>
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<td>interpretation of real historic structures in on-site studies.</td>
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<td><strong>Content</strong></td>
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<td>We study historic constructions in German-speaking Switzerland</td>
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<td>(individual small groups, objects within 2 hrs public transport</td>
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<td>reach from ETH-Hoenggerberg). Each group will be assigned an</td>
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<td>individual tutor (PhD student) who will be present on-site, on</td>
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<td>We will survey, document and analyze a historic construction,</td>
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<td>with particular attention to production traces, constructive</td>
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<td>detail and load-carrying system.</td>
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<td>We will start with introductory classroom lectures and on-site</td>
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<td>followed by individual investigations on site. The progress will</td>
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<td>be pinpointed in three critiques: 1) on site, with individual</td>
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<td>tutor 2) at institute, with professor and institute members</td>
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<td>3) final delivery, at institute, with professor and all institute</td>
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<td>members The detailed schedule of the case studies can be found here:</td>
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<td>Each enrolment obliges the student to visit all compulsory dates</td>
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<td>during the entire semester without interruption.</td>
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<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Detailed instructions on on-site investigations, as well as</td>
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<td>manuscripts on the background, will be provided. It is mandatory to</td>
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<td>read them in due time!</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td></td>
<td>Will be announced during the introductory lectures</td>
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</table>
Elementary knowledge of architectural history and construction.

Semester program:
25.9.20: On site introduction, Rümlang (Glattbrücke).
Courses in HIL E 7 until end of October.
Group work on the object or individual work (at home).

Intermediate crits and final crits at the IDB (HIT, H Level). Details will follow in due time.

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

### 063-0911-00L Future Monuments

This core course (ends with «00L») can only be passed once! Please check this before signing up.

**ITA Pool Introduction to courses within the institute ITA:**
8.9.21, 10-11h, HIB Open Space.

**Abstract**
Heritage conservation is dedicated to the preservation and protection of historical buildings. In this lecture, students will learn about the theoretical positions on historic monuments and the basics of preservation in practice.

**Objective**
In addition to active participation in the discussions, students will be asked to engage with a topic or object of their own choice in order to be able to develop and comprehensively justify their own positions within the context of preservation. Our goal here is to foster students' communication skills and the culture of discussion.

**Content**
The responsible reconstruction and further development of the existing building stock requires knowledge and an understanding of the theoretical positions conservation and the basics of preservation in practice. This core conveys this knowledge to students with the help of selected writings and discusses them in the context of various guest lectures. In addition to dealing with historical buildings, the course is also dedicated to younger (and very young) objects and inventories - for in addition to the preservation of already listed objects, the selection and inventorisation of future protected objects is also one of the core tasks of heritage conservation.
READING LIST

Monographs and edited volumes:


Dehio, Georg, Kunsthistorische Aufsätze. München 1914


Franz, Birgit, Gerhard Vinken und Johanna Blokker (Hg.), Denkmal - Werte - Bewertung, Denkmalpflege im Spannungsfeld von Fachinstitution und bürgerschaftlichem Engagement, Holzminden 2013 (Veröffentlichung des Arbeitskreises Theorie und Lehre der Denkmalpflege e.V., Band 23).

Huse, Norbert (Hg.), Denkmalpflege: Deutsche Texte aus drei Jahrhunderten, München 1984.

ICOMOS Deutschland/ Österreich/ Luxemburg/ Schweiz (Hg.), Monumenta I: Internationale Grundsätze und Richtlinien der Denkmalpflege, Stuttgart 2012.


Petzet, Michael und Gert Mader (Hg.), Praktische Denkmalpflege, Stuttgart/ Berlin/ Köln 1993.


Schmidt, Leo (Hg.), Einführung in die Denkmalpflege, Darmstadt 2008.


Wohllieben, Marion und Georg Mörsch, Georg Dehio und Alois Riegl - Konservieren, nicht restaurieren. Streitschriften zur Denkmalpflege um 1900, Basel 1988 (Bauwelt Fundamente 80)

Hassler, Uta, Langfriststabilität. Beiträge zur langfristigen Dynamik der gebauten Umwelt, Zürich 2011

Fundamentals and legal texts:

Stadt Zürich Hochbaudepartement, Amt für Städtebau, Denkmalpflege und Archäologie (Hg.), Schulhäuser der Stadt Zürich. Spezialinventar Archäologie und Denkmalpflege, September 2008

Stadt Zürich Hochbaudepartement, Amt für Städtebau (Hg.), Bauten, Gärten und Anlagen 1960 bis 1980. Inventarergänzung, August 2013


Denkmalpflegegesetzgebung in den Heimatkantonen der Kursteilnehmenden.

Die Kunstdenkmäler der Schweiz

INSA – Inventare der Heimatkantonen der Teilnehmenden
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Field of Landscape Architecture and Urban Studies

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>063-0701-00L</td>
<td>Methods of Urban Research</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>C. Schmid, I. Apostol, N. Bathla, L. Howe, C. Ting</td>
</tr>
</tbody>
</table>

Abstract
This course conveys an introduction into methods of urban research in social sciences through lectures and accompanying exercises. It treats the basic principles of scientific research, literature research, different forms of participant observation, qualitative interviews (expert interviews and ethnographic interviews), and the analysis of urban qualities.

Objective
This course aims at enabling students of architecture to use sociological analysis as basis for concrete projects in architecture and urban design. It is based on a specific set of methods that is applied in design studios (integrated disciplines) as well as in the master thesis (supplementary discipline sociology).

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<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>063-0703-00L</td>
<td>Architecture of Territory: Territorial Design in Histories, Theories and Projects</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Topalovic</td>
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</tbody>
</table>

Abstract
This lecture series sets up an agenda for widening the disciplinary field of architecture and urbanism from their focus on the city, or the urban in the narrow sense, to wider territorial scales, which correspond to the increasing scales of contemporary urbanisation. It discusses the concepts of territory and urbanisation, and their implications for the work of architects and urbanists.

Objective
The course will enable students to critically discuss concepts of territory and urbanisation. It will invite students to revisit the history of architects' work engaging with the problematic of urbanising territories and territorial organisation. The goal is to motivate and equip students to engage with territory in the present day and age, by setting out our contemporary urban agenda.

The lectures are animated by a series of visual and conceptual exercises, usually on A4 sheets of paper. All original student contributions will be collected and bound together, creating a unique book-object. Some of the exercises are graded and count as proof of completion.
Within the theme My Species, the four guest speakers engaged in fields ranging from art and landscape representation to bioethics and environmental philosophy, will approach territory through the notions such as multispecies, coexistence, and diversity. With a more-than-human perspective on the territory, the guest speakers will elaborate their take on “telling horrible stories in beautiful ways,” debate “the dignity of plants,” expound upon “mankind’s fascination to better the world,” and confer “the non-human turn” and what is to come after.

23. 09. 2021
On Territory
MILICA TOPALOVIĆ

30. 09. 2021
Architecture and Urbanisation
MILICA TOPALOVIĆ

07. 10. 2021
Methods in Territorial Research and Design
MILICA TOPALOVIĆ

14. 10. 2021
Multispecies Worldbuilding
Guest lecture by FEIFEI ZHOU

21. 10. 2021
Better Nature
Guest lecture by ALEXANDRA DAISY GINSBERG

04. 11. 2021
Planetary Urbanisation: Hinterland
MILICA TOPALOVIĆ

11. 11. 2021
Tomatoes Talk, Birch Trees Learn – Do Plants Have Dignity?
Guest lecture by FLORIANNE KOECHLIN

18. 11. 2021
Disappearance of the Countryside
MILICA TOPALOVIĆ

25. 11. 2021
What is Soul? On the Idea of Species Being
Guest lecture by OXANA TIMOFEEVA

09. 12. 2021
Our Common Territories: An Outlook
MILICA TOPALOVIĆ

The lectures will take place on Thursdays, 10.00-12:00, at ONA Fokushalle E7 and on ZOOM.

Lecturer:
Prof. Milica Topalovic

Team:
Prof. Milica Topalovic, Nazlı Tümerdem, Vesna Jovanović

Contact:
Nazlı Tümerdem
tuemerdem@arch.ethz.ch

Our website:
https://topalovic.arch.ethz.ch

#### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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</table>

#### Field of Technology in Architecture

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>063-0605-00L</td>
<td>Computational Structural Design I</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>P. Block, L. Enrique Monzo, J. Lee</td>
</tr>
</tbody>
</table>

#### Number of participants limited to 60.

To participate in this course it is recommended that the student has previously taken the courses Tragwerksentwurf I-IV. This core course (ending with «00L») can only be passed once! Please check before signing up.

ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h.
ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

#### Abstract

Determination of the internal forces and description of the behaviour of load-bearing structures with the help of graphic statics. Design of details and simple dimensioning of these structures. Discussion of reference structures, illustration of the interaction of the structure and the architectural design. Application of all that in an own design.
Objective
Understanding of the relationship between internal forces and the design of load-bearing systems and their connection details. Creative integration of what has been learned into an open design task.

Content
Determination of the internal forces and description of the behaviour of load-bearing structures with the help of graphic statics. Design of details and simple dimensioning of these structures. Discussion of reference structures, illustration of the interaction of the structure and the architectural design. Application of all that in an own design.

Lecture notes
on eQuilibrium
"Skript Tragwerksentwurf I/II/III/IV"
http://www.block.arch.ethz.ch/eq/course/4/lang=de

Printed versions can be bought at the chair of Structural Design Prof. Schwartz.

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

Other Learning Material:


Prerequisites
ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

Teaching Languages: English and German.

063-0607-00L Energy- and Climate Systems III
This core course (ending with «00L») can only be passed once! Please check before signing up.
ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

Abstract
The course ‘Energy- and Climate Systems III’ introduces computational design and analysis methods and tools for climate responsive architectural design. Exercises throughout the semester allow applying new concepts learnt in exemplary architectural design tasks.

Objective
By the end of this course, students will be able to:
- compare and assess passive and active design strategies for bioclimatic buildings
- analyze environmental site characteristics for its climate and (solar) energy potentials
- apply computational simulation tools to support performance-driven designs
- translate design ideas into parametric models and into optimization problems
- synthesize learnt content of the course in exemplary architectural design tasks, serving as a basis for the students’ future design studios and projects

Content
1. Concepts of climate responsive design
2. Computational analysis methods
   - Climate and site analysis
   - Daylight, airflow and energy simulations
   - Energy supply systems optimization models
3. Computational methods for performance driven design
   - Parametric design
   - Sensitivity and uncertainty analysis
   - Single and multi-objective optimization
4. Exercises and walkthroughs
5. Invited expert speakers and panel discussion

Prerequisites
ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.
ZoomLink: https://ethz.zoom.us/j/66588100789

Recommendations:
MSc Arch: Successful participation in the course ‘Energie- und Klimasysteme I + II’.
MSc MIBS / Eng: Successful participation in the course ‘Building Systems’.

All students need to be capable of working with ‘Rhino / Grashopper’ modelling software on ‘Windows’ or willing to acquire the necessary skills before or during the course and are recommended to have completed the online blended learning course ‘Climate responsive architecture with Hive’.

151-8007-00L Urban Physics

Abstract
Urban physics: wind, wind comfort, pollutant dispersion, natural ventilation, driving rain, heat islands, climate change and weather conditions, urban acoustics and energy use in the urban context.

Objective
- Basic knowledge of the global climate and the local microclimate around buildings
- Impact of urban environment on wind, ventilation, rain, pollutants, acoustics and energy, and their relation to comfort, durability, air quality and energy demand
- Application of urban physics concepts in urban design

Content
- Climate Change. The Global Picture: global energy balance, global climate models, the IPCC process. Towards regional climate scenarios: role of spatial resolution, overview of approaches, hydrostatic RCMs, cloud-resolving RCMs
- Urban micro climate and comfort: urban heat island effect, wind flow and radiation in the built environment, convective heat transport modelling, heat balance and ventilation of urban spaces - impact of morphology, outdoor wind comfort, outdoor thermal comfort,
- Urban energy and urban design. Energy performance of building quarters and cities, decentralized urban energy production and storage technologies, district heating networks, optimization of energy consumption at district level, effect of the micro climate, urban heat islands, and climate change on the energy performance of buildings and building blocks.
- Wind driving rain (WDR): WDR phenomena, WDR experimental and modeling, wind blocking effect, applications and moisture durability
- Pollutant dispersion, pollutant cycle : emission, transport and deposition, air quality
- Urban acoustics, noise propagation through the urban environment, meteorological effects, urban acoustic modeling, noise reduction measures, urban vegetation
The course lectures and material are provided online via Moodle. For MIBS Master students 151-8011-00L Building Physics Theory & Application is a pre-requisite for this course or instructor permission. For others no prior knowledge is required.

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<tr>
<th>Code</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>063-0601-00L</td>
<td>Building Process: Economy</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>H. Reichel</td>
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<tr>
<td>Abstract</td>
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<tr>
<td>Objective</td>
<td>The demonstration of economic considerations within the design and construction process of buildings is the main focus of the diploma elective subject.</td>
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<tr>
<td>Content</td>
<td>To grasp the coherences of costs, income and income return.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The case studies in the lectures as well as the processing of individual topics within the framework of elective work permit and require students active participation.</td>
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<tr>
<td>Literature</td>
<td>The recordings of the lectures are available on the MAP under the link <a href="https://map.arch.ethz.ch">https://map.arch.ethz.ch</a> (book symbol at the top right).</td>
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<tr>
<td>063-0611-00L</td>
<td>The Digital in Architecture II (Exercise)</td>
<td>W</td>
<td>2</td>
<td>1V+2U</td>
<td>J. Medina Ibañez</td>
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<tr>
<td>Prerequisite: Successful completion of the course &quot;Structural Design VI&quot; (063-0606-00L), &quot;Design III&quot; (052-0541/43/44) or &quot;Das Digitale in der Architektur&quot; (063-0610-00L).</td>
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<tr>
<td>Objective</td>
<td>The demonstration of economic considerations within the design and construction process of buildings is the main focus of the diploma elective subject. Alongside determining basic principles, case studies play an important role in teaching. The economic factors of building construction are examined and the specific decision process is simulated.</td>
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<tr>
<td>Content</td>
<td>To grasp the coherences of costs, income and income return.</td>
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<tr>
<td>Abstract</td>
<td>The course is centered around a design exercise where the form should be the result of the flow of internal forces and the detailing concept combined with the quality of architectural space. The focus is on structural and load bearing issues with respect to realization implemented in an architectural design.</td>
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<tr>
<td>Objective</td>
<td>Understanding of structural design as translation of structural concepts into building materials with respect to design concepts.</td>
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<tr>
<td>Content</td>
<td>The course is centered around a design exercise where the form should be the result of the flow of internal forces and the detailing concept combined with the quality of architectural space. The focus is on structural and load bearing issues with respect to realization implemented in an architectural design.</td>
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### Architectural Design

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>063-0853-21L</td>
<td>Subject Semester HS21 in the Field of History and Theory in Architecture (gta, Prof. Ursprung) allocation only after consultation with the professor (meetings as required and after consultation with the chair).</td>
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<tr>
<td>Notice</td>
<td>The application deadline is Wednesday September 8, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to</td>
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<tr>
<td>ZoomLink</td>
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Autumn Semester 2021
Students are invited to identify and investigate their own specific case studies that pertain to this theme. The Studio will teach students to develop a new teaching form for the history and theory of architecture. Students will be familiar with theories and practices of attention, they will learn to take position in a field, they will practice argumentation and increase their writing skills.

Our aim is to increase the knowledge and sensitivity of architecture students toward the issue of attention, to make their voices heard and paying attention: a collective manifesto.

Attention is a rare commodity. How do we deal with attention? How is it manipulated? Who pays?

Students produce autonomous texts.

Our Studio aims to increase the knowledge and sensitivity of architecture students toward the issue of attention, to make their voices heard and paying attention: a collective manifesto.

The application deadline is Wednesday, September 8, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

The application deadline is Wednesday, September 8, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

The theme of this History Research Studio is 'Female Agency in Architecture before 1850'. The Studio aims at exploring the crucial role women played in the birth, life and afterlife of buildings in the early modern period. We will study female patronage, authorship, and criticism in architecture.

The structure of the studio will follow an input-exchange-output model. All members of the chair will provide input, to both the theme and method, as well as examples and references of research. There is also room for students to read and discuss together with the material prepared for them (short texts, summaries and reading lists) and the materials they found. Weekly group meetings and individual supervision by the chair members will help students in academic research and writing. Exchanges with the researchers at the chair are also beneficial to further develop their research themes and teaching.

Women acquired a major role in architectural patronage in eighteenth-century France and England, when they came to independently design and commission innovative mansions and dwellings. They stand in a tradition of major female builders in early-modern (sixteenth- and seventeenth-century) Italy and in Ottoman Turkey. The relationship between architect and patron surfaces in different types of buildings commanded by women: stately residences (hôtels urbains) and emerging types as pavilions and petites mansions. These women excited their influence in the various aspects of the design process. Female patrons used their expertise in determining the layouts of their dwellings and in arranging spaces that reflected as much their daily lives as special occasions. They tell us about women's lifestyles, their use of specific spaces, and the expression such spaces should have, as well as about their social and economic situations. While many of these patrons were women of fortune, from aristocracy, the period also sees a changing female clientele emerge with collectors, artists, dancers, actresses, writers and mistresses (the Petit Trianon for Madame de Pompadour for example). Furthermore, in this period women thrilled to design and construction, and in drawing up plans for new buildings, when acting as a patron. Both as a patron and as a user of buildings women acted as a critical voice of how to design architecture from the point of view of the user of architectural spaces, be it in a domestic or a more public setting.

This Master Studio invites students to adopt female agency as a primary investigative territory to critically examine the ways in which architecture is produced, conceptualised and historiscised in a particular cultural and historical context. It was in a wide array of media that constituted architectural debate that the female voice was heard and influenced the larger debate. By examining the female perspective of this studio aims to open up the corpus and historiography of thinking about buildings.

While we understand the necessity of a canonical history the Studio actively searches and tests approaches and methods of enquiry that challenge that canon and propose a different history. By examining the professional, artistic, authorial and cultural role of women in architecture the courses and meetings of the semester will offer an opportunity to look afresh at architectural history and theory of the early modern period.

A student can only register once for a “Fachsemester” during the Master studies!

For further information, please see: https://ursprung.arch.ethz.ch/courses/who-cares/information
Prerequisites / notice
Places for this Subject Semester are limited. Please send your candidacy by email (a 300-word motivation letter and a 300-word statement on your topic of interest) to: professur.delbeke@gta.arch.ethz.ch
See also the website of the chair: https://delbeke.arch.ethz.ch/courses

Deadline for application is Wednesday, September 8, 2021, 20.00h. You will receive a message on your acceptance for the Fachsemester by Thursday, September 9, 2021, 14.00 h. This means rejected students can then still choose a design class for HS 2021.

A student can only register once for a Subject Semester during the Master studies!

063-0953-21L Subject Semester HS21 in the Field of Historic Building Research and Conservation (IDB, Prof Holzer)

A student can only register once for a "Fachsemester" during the Master studies!

The application deadline is Friday September 3, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

Abstract
The subject semester (to choose out of two topics) includes the individual, independent processing of a specific task, whereby the relevance of the respective discipline is examined with regard to the specific architectural and design aspects of the task.

Objective
The subject semester includes the individual, independent processing of a specific task, whereby the relevance of the respective discipline is examined with regard to the specific architectural and design aspects of the task.

Content
The subject of the semester is defined by the chair and published on the website:

https://holzer.arch.ethz.ch/en/education/Fachsemester.html

Prerequisites / notice
A student can only register once for a "Fachsemester" during the Master studies!

The application deadline is Sunday December 26, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Wednesday, January 26, 2022, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

The requirements for this subject semester are interest in the material as well as experience with and knowledge of historical wooden structures and the methods of building research.

Ideally, the student has heard Prof. Holzer’s lectures on construction history or does so during the semester. It is also beneficial to have attended the case studies exercise.

Taught competencies

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

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

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork not assessed
Customer Orientation assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation not assessed

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

063-0655-21L Subject Semester (Fachsemester) HS21 in the Field of Technology in Architecture (ITA, Prof. Schlüter)

A student can only register once for a "Fachsemester" during the Master studies!

The application deadline for this "Fachsemester" is Wednesday, September 1, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Friday, September 3, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

Abstract
In this research semester, we address the topic of Zero Emissions Building Design, which integrates aspects of energy, materials and technology, human behaviour and comfort into architectural design, aspiring synergetic design solutions.

Objective
After successfully concluding the research semester students can identify concepts and relevant design parameters for Zero Emissions Building Design and develop integrated architectural design strategies. They know how to select and use appropriate simulation and analysis tools to qualify and quantify their design solutions and visualize their concepts using both technical schematics as well as architectural drawings and visualizations.
First, students will be introduced to core concepts of Zero Emissions Building Design and discuss leading works and examples on a global scale. In combination with excursions and site visits (if possible), a catalogue of criteria and metrics for the development of their integrated design concepts will be developed.

Participants will work on an urban retrofit case study in a moderate climate. The analysis departs at analyzing the site, its climate, the status quo of the building and relevant architectural/urban parameters. After assessing the potentials for reducing energy demand and local renewable energy supply, students will develop integrated design concepts targeting zero carbon over the building lifecycle, both for building operation and construction/materials.

Using low-barrier modelling, simulation and optimization toolsets (preferably Rhino / Grasshopper, HIVE, etc.) the design concepts will be assessed and discussed both numerically as well as architecturally / aesthetically. For further development, students choose one component or aspect central to their design concept.

Students will document the process and the results both numerically as well as architecturally, which will then be discussed with a final jury.

The working mode is an individual design research studio with weekly group meetings and reviews. We expect good base knowledge on sustainable construction and energy- and climate systems. Prior knowledge in parametric design tools (Rhino) and/or simulation is a plus.

A student can only register once for a "Fachsemester" during the Master studies!

Apply with CV, concise motivation letter and your current Transcript of Records before September 1, 2021, to: ilias.hischier@arch.ethz.ch

Your participation in the Subject semester will be confirmed by September 3, 2021.

#### 063-0857-21L

**Subject Semester (Fachsemester) HS21 in the Field of W History and Theory in Architecture (Avermaete)**

<table>
<thead>
<tr>
<th>Credits</th>
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<tbody>
<tr>
<td>14</td>
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Enrolment in agreement with the chair only.

Meetings as required and in consultation with the chair.

A student can only register once for a "Fachsemester" during the Master studies!

The application deadline is Wednesday 8th September 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

#### Abstract

Housing Commons and the City: Zurich

Focuses on the housing commons of Zurich, namely collectively owned, non-profit forms of housing ownership (e.g. cooperatives). In the ways that they have been produced, managed, used, maintained, and appropriated, housing commons offer new perspectives to think about contemporary urban challenges such as densification, housing demand, and sustainability.

#### Objective

The Research Studio has two objectives. First, to develop an ‘Archaeology’ of Zürich’s housing commons. In this part, the work of the urban historian or theoretician is understood as an archaeological venture. The collective residential stock, as well as the integrated common facilities that often accompany it, will be systematically analyzed as the outcome of codes and as reliant on established practices of ‘commoning’. The result will be a catalogue of city’s cooperative and related networks, illustrating how these provide frameworks for ‘commoning’ and how, as urban figures, they are integrated into and impact upon the city fabric.

Secondly, we will develop an ‘Assemblage’ of Zürich’s housing commons by scrutinizing how they are experienced, practised, and developed in the city. To this end, we will analyze the character and role of cooperative and not-for-profit housing, be they in the inner city fabric (historically so-called ‘colonies’), in the city’s fast-densifying residential and post-industrial suburbs (‘settlements’), as well as newer forms of housing ideology indirectly indebted to the social movements of the 1980s, and exploring new forms of communal living and typological innovation through the historical legal framework of housing cooperatives. We will investigate the relations between typological definition and commoning practices, and the negotiations they entail between experts and non-experts, formal and informal agencies, the city and grassroots action groups.

The result of the Research Studio will be a Retroactive Manifesto for the city of Zürich, in which the past, present and future roles of housing commons in the city will be discussed, as a more comprehensive project for the city as we know it and as it might evolve.

#### Content

Housing Commons and the City: The Case of Zurich

This Research Studio focuses on the housing commons of Zurich. By ‘housing commons’ we mean various collectively owned, non-profit forms of housing ownership such as associations, public (municipal) housing, and cooperatives, all formats that have built up the backbone of the city’s affordable housing policy since the early 1990s. A long-standing alliance with the local government, financial subsidies historically ratified in popular referendums, and the possibility of leasing city-owned land for development have rendered housing commons prominent, in a housing sector otherwise dominated by market rental and private ownership. About a quarter of the city’s residential stock qualify as collectively owned housing, a ratio set up to increase to a third by 2040. In a city where 1-person households still make up almost half of the entire residential stock, housing commons are exemplary as models for sustainable densification and typological innovation.

In this research studio we will explore how housing commons have been produced, managed, used, maintained, and appropriated, how are they represented in the city, how they are iconographically or typologically distinguished from the housing on the market. We are particularly interested in how housing commons have contributed to ease the chronic housing shortage in the city, and might continue to do so in the future? We hold that housing commons offer us new perspectives to think about contemporary challenges such as densification, a growing housing demand, and sustainable urban living.

Cities have always been places based on common resources and common practices. While designing and constructing the architecture of the city, architects, urban designers, builders, and inhabitants have had to engage with common resources located in particular places and geographies: inherited common-pool resources (water, nature, air); material common-pool resources (clay, brick, stone, wood); and immaterial common-pool resources (craft, knowledge). This understanding of the city, as related to common resources and practices, has gained renewed attention, as neoliberalism replaces ever-shrinking welfare structures, and global urbanization is accompanied by rising inequality. It is not only architects and urban designers who are again becoming interested in alternative principles of governing common resources, but also political movements and society at large. Some of these issues – generally called ‘the commons’ – have also received growing academic attention in the last decades within the fields of critical urban studies, urban history, urban geography and the social sciences. This Research Studio continues the studio’s investigations into the rich history of ‘the commons’ in the city of Zürich by focusing on its residential infrastructures. The ‘housing commons’ will be investigated from architectural, urban, typological, environmental and material perspectives. We will explore how common practices and resources have affected their development in the city, and conversely how the built housing commons enable and structure common practices. The research will unlock an alternative reading of the urban and architectural qualities of the built environment of the city.
Methodology: Exploring the Tools and Knowledge of the Architect

The main hypothesis of the Research Studio is that historical and theoretical research can gain from a profound use of the tools and knowledge of an architect. During the Research Studio students will employ specific architectural tools, such as drawing, writing, and model making to explore historical and theoretical realities. Students will be urged to explore various methods of composing analytical and interpretative drawings. They will reflect upon the capacity of drawing methods from the field of architecture, such as plan drawing, sectional drawings, mappings, serial visions, public drawings, diagramming and perspective representations to act as tools of historical and theoretical research. At the same time, they will be asked to investigate various analytical and interpretative modes of scale-model making. Students may work with different types of models (structural models, mass models, counter form models, landscape and territorial models) as ways to historically or theoretically explore the reality of the city.

Far from being simple graphic or artefactual restitutions of the city, these drawings and models will create morphological, thematic or theoretical links between various occurrences in the city. These methods of drawing and model making will be combined with more conventional investigative techniques in the fields of history and theory such as discourse analysis, iconographic studies and compositional investigation, to support a better historical or theoretical understanding of specific occurrences and conditions in the city of Zürich. Students will also be stimulated to use their spatial, formal, material and constructive architectural knowledge to offer alternative historical or theoretical interpretations of the reality that they encounter in the archives, in the library or in the city. They will be asked to activate their specific spatial, typological, compositional, technical, material and constructive expertise to probe into the various historical layers of the architecture of the city in newfangled ways.

Within the general theme of housing commons, students will be guided to identify their own sub-theme, as well as explore their own different methodologies of doing research. During the Research Studio students will confront their empirical knowledge (about space, typology, composition, technique, material and construction), pertaining to the autonomy of architecture, with other types of knowledge (on politics, economy, the social and cultural) that belong to the heteronomy of architecture. In the relation between autonomous and heteronomous knowledge, a new understanding of the city will be constructed. The combination of these tools and methods will offer an in-depth mode of historical and theoretical research, wherein the students will retro-actively explore the spatial, formal, material and constructive features of a particular situation to uncover and reconstruct the logics that have led to a certain urban condition. On the basis of this research, students will be able to develop an architectural hypothesis of the developments in the city of Zürich.

A student can only register once for a "Fachsemester" during the Master studies!

The application deadline is Wednesday 8th September, 2021, 8 p.m. You will receive a message about acceptance or rejection for the subject semester by Thursday, September 9, 2021, 2 p.m. at the latest. Students who have been rejected have the opportunity to choose a design class.

Self-dependent work.

Enrollment on agreement with the chair only.

Meetings as required and after consultation with the chair (Wednesdays).

The collective and individual projects together will offer an alternative reading, which retro-actively traces the urban territory and architectural quality of the city of Zürich back to the local common resources and common practices. The different materials – texts, drawings, models – will be combined in an atlas, which presents this alternative reading to a larger audience.

Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies

Communication assessed
Cooperation and Teamwork assessed
Customer Orientation not assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity assessed
Negotiation not assessed

Domain D - Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management assessed

Autumn Semester 2021

052-1201-21L Preparation Semester Free Master Thesis HS21 W 14 credits 16A Lecturers

Preparation semester for a self-determined Master thesis within the Department of Architecture. of ETH Zurich.

Self-dependent development of a program, according to which one intends to realize a free master thesis in the following semester.

Focus Work

Realization in the respective fields of the institutes. Definition of topics by professors, in consultation with the students. The content may also refer to an elective course.

The performance assessment comprises either a purely written examination followed by an oral examination or a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by an oral exam. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and knowledge gained.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.

Field of Historic Building Research and Conservation

Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).

Performance assessment: Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by an oral exam. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and possibly gained knowledge.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.
### Field of Design and Architecture

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

**Performance assessment:** Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by an oral exam. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and possibly gained knowledge.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.

### Field of History and Theory of Architecture

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

**Performance assessment:** Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by a comprehensive examination. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and possibly gained knowledge.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.

### Field of History and Theory of Architecture

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

**Performance assessment:** Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by an oral exam. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and possibly gained knowledge.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.
In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4. It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

### Field of Landscape Architecture and Urban Studies

**Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).**

**Performance assessment:** Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.

At least one focus work is a written work followed by an oral exam. The written work fulfills the criteria of a scientific paper in a formal sense. In addition to the design, crafting or drawing part, it also includes a written description of the question, methodology and possibly gained knowledge.

A creative, crafting or graphic focus work is shown in a public exhibition, a purely written focus work is accessible to the public.

**Information on exams and grades:** Art. 29 of the MSc D-ARCH regulations.

**Performance assessment** comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4. It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

#### Course Details

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<td>Focus Work HS21 in the Field Landscape and Urban Studies (LUS)</td>
<td>W</td>
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**Abstract**

Indentation work of the Institute LUS, of which the content can also refer to an elective subject.

**Objective**

Development of skills and competences in a special area / sub-area of architectural theory or practice.

**Content**

In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The content of the in-depth work can also relate to the content of an elective course.

The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis.

The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved.

The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4. It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term "dropout".

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations).

If more than one "in-depth study" course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

#### Course Details

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<th>Number</th>
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<td>103-0569-00L</td>
<td>European Aspects of Spatial Development</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Peric Momcilovic</td>
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**Abstract**

Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.
Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making

- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the notion of planning culture and planning system; planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

The documents for the lecture will be provided at the moodle.

Obligatory literature:

Recommended literature:

Goverance models:

Planning models:

EU as a political context:

Territorial cooperation in Europe:

Planning families and cultures:

Planning systems in Europe:

- European transnational initiatives

Only for master students, otherwise a special permission by the lecturer is required.

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

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

Field of Technology in Architecture

Definition of topics by professors, in consultation with the students (student's proposal / content of an elective course).

Performance assessment: Purely written examination followed by an oral examination OR a creative, manual or drawing work, including a description, followed by an oral examination.
In-depth work is carried out in the respective subject areas of the institute. The professors determine the topics in consultation with the students. The performance assessment comprises either a purely written work with a subsequent oral examination or a creative, technical or graphic work, including a description, with a subsequent oral examination. At least in the case of one in-depth thesis, the performance assessment must take the form of a purely written work with a subsequent oral examination (Regulations Paragraph 2 Letter a). In formal terms, the written work must meet the criteria of an academic paper. In addition to the creative, manual or drawing part, it includes a written description of the question, the methodology and the possible gain in knowledge of the work.

The students take the oral examination with the professor with whom they have discussed the topic of the in-depth thesis. The written or creative, manual or drawing work and the oral examination are each assessed individually. These two assessments are offset against each other and result in the overall grade for the in-depth work. Paragraph 7 remains reserved. The oral examination can only be taken if the written work or the creative, technical or graphic work is sufficient.

A thesis is passed if the overall grade is at least 4. It is considered not passed if the overall grade is below 4; if the written or creative, technical or graphic work is unsatisfactory and therefore the oral examination cannot be taken; in such a case, the failure will be noted with the term “dropout”.

An in-depth thesis that has not been passed cannot be repeated. In order to acquire the required CP, a further in-depth work must be carried out and the performance must be assessed with an overall grade of at least 4. The number of attempts is limited (see regulations). If more than one “in-depth study” course unit is not passed, the course is considered to have been definitively failed, which leads to exclusion from the course.

The creative, craft or drawing in-depth work is publicly exhibited. Purely written in-depth theses are made publicly available.

Prerequisites / notice
The subjects can be proposed by the students. In consultation with the professors of architecture, the fixed topics are binding (see Art. 29 Reg. 201 MSc Architecture).

### Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>063-0141-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>40D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

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

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Ultimate deadline to unsubscribe or enroll for the Master Thesis is 17.11.2021. Deleting a reservation after this date is prohibited.

The master’s thesis is the completion of the Master's degree.

It shows the students’ ability to work independently and is a proof of the successful completion of their studies.

The Master’s thesis is supervised by a design professor D-ARCH. The students can choose one of the topics presented by the D-ARCH or - after approval by the head of the work - a free, self-chosen topic. Further details are regulated in Articles 31-38.

### Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Number of participants limited to 21.

This doctoral seminar organised by the D-BAUG platform on data science and machine learning aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

Students will:
- Critically read scientific papers on the recent developments in machine learning
- Put the research in context
- Present the contributions
- Discuss the validity of the scientific approach
- Evaluate the underlying assumptions
- Evaluate the transferability/adaptability of the proposed approaches to own research
- (Optionally) implement the proposed approaches.
With the increasing amount of data collected in various domains, the importance of data science in many disciplines, such as infrastructure monitoring and management, transportation, spatial planning, structural and environmental engineering, has been increasing. The field is constantly developing further with numerous advances, extensions and modifications.

The course aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

Each student will select a paper that is relevant for his/her research and present its content in the seminar, putting it into context, analyzing the assumptions, the transferability and generalizability of the proposed approaches. The students will also link the research context of the selected paper to their own research, evaluating the potential of transferring or adapting it. If possible and applicable, the students will also implement the adapted algorithms. The students will work in groups of three students, where each of the three students will be reading each other’s selected papers and providing feedback to each other.

Participants are expected to possess elementary skills in statistics, data science and machine learning, including both theory and practical modelling and implementation. The seminar targets students who are actively working on related research projects.

### Seminar Weeks

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>051-0911-21L</td>
<td>Seminar Week Autumn Semester 2021</td>
<td>W</td>
<td>2 credits</td>
<td>3A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Objective

The seminar week is obligatory for students of all semesters. There are many and varied study contents.

The students will be enabled to discuss narrowly formulated factual questions in small groups and in direct contact with the professors.

### GESS Science in Perspective

see GESS Science in Perspective: Language Courses

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-ARCH.

### Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-1100-AAL</td>
<td>Architectural Design V-IX (Part 1)</td>
<td>E-</td>
<td>14 credits</td>
<td>16U</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

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

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

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php)

Project grading at semester end is based on the list of enrolments on 2.11.21 (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Objective

Requirements.

Content

Session requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-1101-AAL</td>
<td>Architectural Design V-IX (Part 2)</td>
<td>E-</td>
<td>14 credits</td>
<td>16U</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

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

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

Please register (www.mystudies.ethz.ch) only after the internal enrolment for the design classes (see http://www.einschreibung.arch.ethz.ch/design.php)

Project grading at semester end is based on the list of enrolments on 2.11.21, 24:00 h (valuation date) only. This is the ultimate deadline to unsubscribe or enroll for the studio.

Objective

Requirements.

Content

Session requirements.

### Architecture Master - Key for Type

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

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>ECTS</th>
<th>European Credit Transfer and Accumulation System</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td></td>
<td>Special students and auditors need special permission from the lecturers.</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
<td></td>
<td></td>
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<tr>
<td>A</td>
<td>independent project</td>
<td></td>
<td></td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
<td></td>
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</tr>
</tbody>
</table>

Special students and auditors need special permission from the lecturers.
Atmospheric and Climate Science Master

Modules

Weather Systems and Atmospheric Dynamics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1221-00L</td>
<td>Dynamics of Large-Scale Atmospheric Flow</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>H. Wernli, L. Papritz</td>
</tr>
</tbody>
</table>

Objective
Understanding the dynamics of large-scale atmospheric flow

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites / notice
Physics I, II, Environmental Fluid Dynamics

Climate Processes and Feedbacks

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1235-00L</td>
<td>Cloud Microphysics</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>U. Lohmann, N. Shardt</td>
</tr>
</tbody>
</table>

Objective
The learning objective of this course is that students understand the formation of clouds and precipitation and can apply learned principles to interpret atmospheric observations of clouds and precipitation.

Content

Lecture notes
This course will be designed as a reading course in 1-2 small groups of 8 students maximum. It will be based on the textbook below. The students are expected to read chapters of this textbook prior to the class so that open issues, fascinating and/or difficult aspects can be discussed in depth.

Literature
Lamb and Verlinde: PHYSICS AND CHEMISTRY OF CLOUDS, Cambridge University Press, 2011

Prerequisites / notice
Target group: Doctoral and Master students in Atmosphere and Climate
Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories, assessed
Techniques and Technologies, assessed

Domain B - Method-specific Competencies

Analytical Competencies, assessed
Decision-making, not assessed

Domain C - Social Competencies

Communication, assessed

Domain D - Personal Competencies

Critical Thinking, assessed
Self-direction and Self-management, assessed

701-1251-00L Land-Climate Dynamics

W 3 credits  2G  S. I. Seneviratne, R. Padrón Flasher

Number of participants limited to 36.
Priority is given to the target groups:
- Master Environmental Science,
- Master Atmospheric and Climate Science and
- PhD D-USYS
until September 20th, 2021.
Waiting list will be deleted September 27th, 2021.

Abstract

The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy and water balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

Objective

The students can understand the role of land processes and associated feedbacks in the climate system.

Lecture notes

Powerpoint slides will be made available

Prerequisites / notice

Prerequisites: Introductory lectures in atmospheric and climate science


and/or


Atmospheric Composition and Cycles

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
701-1239-00L | Aerosols I: Physical and Chemical Principles | W | 4 credits | 2V+1U | M. Gysel Beer, D. Bell, E. Weingartner

Abstract

Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

Objective

Physical and chemical principles:
The students...
- know the processes and physical laws of aerosol dynamics.
- understand the thermodynamics of phase equilibria and chemical equilibria.
- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.

Experimental methods:
The students...
- know the most important chemical and physical measurement instruments.
- understand the underlying chemistry and physics.

Environmental impacts:
The students...
- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
- are aware of the health impacts of atmospheric aerosols.

Lecture notes

materiel is distributed during the lecture

Literature


Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories, assessed
Techniques and Technologies, assessed

Domain B - Method-specific Competencies

Analytical Competencies, assessed
Decision-making, not assessed

Domain C - Social Competencies

Communication, assessed

Domain D - Personal Competencies

Adaptability and Flexibility, not assessed
Creative Thinking, assessed

701-1233-00L Stratospheric Chemistry

W 4 credits  2V+1U  T. Peter, G. Chiado

Abstract

The lecture gives an overview on the manifold reactions which occur in the gas phase, in stratospheric aerosol droplets and in polar cloud particles. The focus is on the chemistry of stratospheric ozone and its influence through natural and anthropogenic effects, especially the ozone depletion caused by FCKW in mid-latitude and polar regions as well as the coupling with the greenhouse effect.
Objective

The students will understand the gas phase reactions in the stratosphere as well as reactions and processes in aerosol droplets and polar stratospheric clouds.

The students will understand the most important aspects of stratospheric dynamics and the greenhouse gas effect in troposphere and stratosphere.

The students will also acquire a good understanding of the coupling between stratospheric ozone and climate change.

Furthermore, they will practise to explain fundamental concepts in stratospheric chemistry by means of scientific paper presentations.

Content

Short presentation of thermodynamical and kinetic basics of chemical reactions: bi- and termolecular reactions, photo-dissociation.

Introduction to the chemical family concept: active species, their source gases and reservoir gases. Detailed treatment of the pure oxygen family (odd oxygen) according to the Chapman chemistry. Chemical reactions of the oxygen species with nitric oxides, active halogens (chlorine and bromine) and odd hydrogen. Ozone depletion cycles. Methane depletion cycles. Heterogeneous chemistry on the background aerosol and its significance for heavy air traffic. Chemistry and dynamics of the ozone hole: Formation of polar stratospheric clouds and chlorine activation.

Lecture notes

Documents are provided in the contact hours.

Literature


Prerequisites / notice

Prerequisites: Basics in physical chemistry are required and an overview equivalent to the bachelor course in atmospheric chemistry (lecture 701-0471-01) is expected.

701-1233-00 V starts in the first week of the semester. The exercises 701-1233-00 U will start only in the 2nd week of the semester.

★★ Climate History and Paleoclimatology

Number

Title

Type ECTS Hours

W 3 credits

2G

H. Stoll, I. Hernández Almeida, H. Zhang

Objective

1. Overview of elements of the climate system and earth energy balance

2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Paleocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?

3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?

4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems? Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?

5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

★★ Hydrology and Water Cycle

Number

Title

Type ECTS Hours

W 3 credits

2G

S. I. Seneviratne, R. Padrón Flasher

Objective

The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy and water balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

Prerequisites / notice

Powerpoint slides will be made available

Abstract

The students can understand the role of land processes and associated feedbacks in the climate system.

Prerequisites: Introductory lectures in atmospheric and climate science


701-1253-00L

Analysis of Climate and Weather Data

Does not take place this semester.

Abstract

An introduction into methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of deterministic and probabilistic predictions, principal component analysis.

Students participate in the theoretical concepts and purpose of methods, can apply them independently and know how to interpret results professionally.

Objective

Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.

The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Lecture notes
- Documentation and supporting material:
  - slides used during the lecture
  - exercise sets and solutions
  - R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

Literature
For complementary reading:

Prerequisites / notice
Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umweltwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

651-4053-00L Boundary Layer Meteorology 4 credits 3G M. Rotach, P. Calanca

Abstract
The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Objective
Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer Flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

Content
- Introduction
- Turbulence
- Statistical tratment of turbulence, turbulent transport
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Spectral characteristics
- Concepts for non-ideal boundary layer conditions

Lecture notes
available (i.e. in English)

Literature

Prerequisites / notice
Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

102-0468-10L Watershed Modelling 6 credits 4G P. Molnar

Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many practical applications. A comprehensive exercise block builds on the lectures with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences), Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Electives
The students are free to choose individually from the entire course offer of ETH Zürich and the universities of Zürich and Bern.

Weather Systems and Atmospheric Dynamics
Courses are only offered in Spring Semester.

Climate Processes and Feedbacks
Two additional courses are offered in Autumn Semester by University of Berne.
This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic theory, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Objective
Understanding the dynamics of large-scale atmospheric flow

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature

Prerequisites / notice
Physics I, II, Environmental Fluid Dynamics

651-4057-00L Climate History and Palaeoclimatology

Abstract
Climate history and palaeoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in general monsoon systems? Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

701-1257-00L European Climate Change

Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
- observational datasets, observation and detection of climate change;
- underlying physical processes and feedbacks;
- numerical and statistical approaches;
- currently available projections.

Objective
At the end of this course, participants should:
- understand the key physical processes shaping climate change in Europe;
- know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
- be familiar with relevant observational and modeling data sets;
- be able to tackle simple climate change questions using available data sets.

Content
Contents:
- global context;
- observational data sets, analysis of climate trends and climate variability in Europe;
- global and regional climate modeling;
- statistical downscaling;
- key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects;
- projections of European and Alpine climate change

Lecture notes
Slides and lecture notes will be made available at http://www.iac.ehzedu.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice
Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

Atmospheric Composition and Cycles

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>102-0635-01L</td>
<td>Air Pollution Control</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Wang, B. Buchmann</td>
</tr>
</tbody>
</table>

Abstract
The lecture provides in the first part an introduction to the formation of air pollutants by technical processes, the emission of these chemicals into the atmosphere and their impact on air quality. The second part covers different strategies and techniques for emission reduction. The basic knowledge is deepened by the discussion of specific air pollution problems of today's society.

Objective
The students gain general knowledge of the technical processes resulting in air pollution and study the methods used for air pollution control. The students can identify major air pollution sources and understand the methods for measuring pollutants, collecting and analyzing data. The students can suggest and evaluate possible control methods and equipment, design control systems and estimate their efficiency and efforts.

The students know the different strategies of air pollution control and are familiar with their scientific fundamentals. They are able to incorporate goals concerning air quality into their engineering work.
The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Procedures for the removal of gaseous pollutants and the description of the driving forces involved, as well as the equilibrium and the kinetics of the relevant processes (absorption, adsorption as well as thermal, catalytic and biological conversions).

Discussion of the technical possibilities to solve the actual air pollution problems.

Lecture notes
Brigitte Buchmann, Air pollution control, Part I
Jing Wang, Air pollution control, Part II
Lecture slides and exercises

Literature
List of literature included in script

Prerequisites / notice
College lectures on basic physics, chemistry and mathematics.

Language of instruction: In German or in English.

<table>
<thead>
<tr>
<th>651-4053-05L</th>
<th>Boundary Layer Meteorology</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>M. Rotach, P. Calanca</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).</td>
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<tr>
<td><strong>Content</strong></td>
<td>- Introduction</td>
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<td>- Turbulence</td>
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<td>- Statistical tratment of turbulence, turbulent transport</td>
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<td>- Conservation equations in a turbulent flow</td>
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<td>- Closure problem and closure assumptions</td>
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<td>- Scaling and similarity theory</td>
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<td>- Spectral characteristics</td>
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<td></td>
<td>- Concepts for non-ideal boundary layer conditions</td>
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</table>
Sedimentology II: Biological and Chemical Processes

Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

At the end of the course students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. be able to calculate an age based on data of the six methods studied.
3. choose which dating method (or combination of methods) is suitable for a certain field problem.
4. critically read and evaluate the application of dating methods in scientific publications.

Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

The grading of students is based on in-class exercises and end-semester examination.

Climate History and Paleoeclimatology

Two courses are offered in Autumn Semester at University of Berne. ETH courses are only offered in Spring Semester.

Fall Semester 2021

651-4041-00L Sedimentology I: Physical Processes and Sedimentary Systems

Abstract
Sediments preserved a record of past landscapes. This course focuses on understanding the processes that modify sedimentary landscapes with time and how we can read this changes in the sedimentary record.

Objective
The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change. They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

Content
Details on the program will be handed out during the first lecture. We will attribute the papers for presentation on the 26th, so please be here on that day!

Literature
The sedimentary record of sea-level change
Angela Coe, the Open University.

Prerequisites / notice
The grading of students is based on in-class exercises and end-semester examination.

651-4043-00L Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems

Prerequisite: Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

Abstract
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

Objective
-You will understand chemistry and biology of the marine carbonate system
-You will be able to relate carbonate mineralogy with facies and environmental conditions
-You will be familiar with cool-water and warm-water carbonates
-You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle
-You will be able to recognize links between climate and marine carbonate systems (e.g. acidification of oceans and reef growth)
-You will be able to use geological archives as source of information on global change
-You will have an overview of marine sedimentation through time

Content
-carbonates, chemistry, mineralogy, biology
-carbonate sedimentation from the shelf to the deep sea
-carbonate facies
-cool-water and warm-water carbonates
-organic-carbon and black shales
-C-cycle, carbonates, Co2 : CO2 sources and sink
-Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
-marine sediments trough geological time
-carbonates and evaporites
-lacustrine carbonates
-economic aspects of limestone

Lecture notes
no script. scientific articles will be distributed during the course

Literature
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems"

Prerequisites / notice
The grading of students is based on in-class exercises and end-semester examination.

651-4901-00L Quaternary Dating Methods

Abstract
Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Content
1. Introduction: Time scales for the Quaternary, Isotopes and decay
2. Radiocarbon dating: principles and applications
3. Cosmogenic nuclides: 3He,10Be, 14C, 21Ne, 26Cl, 36Cl
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology and ice cores chronologies
7. Cs-137 and Pb-210 (soil, sediments, ice core)
8. Summary and comparison of results from several dating methods at specific sites

Prerequisites / notice
Visit to radiocarbon lab, cosmogenic nuclide lab, accelerator (AMS) facility.

Visit to Limno Lab and sampling a sediment core
Optional (individual): 1-5 days hands-on radiocarbon dating at the C14 lab at ETH Hoenggerberg

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets (Exercises)
The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale. Students learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.

The course provides an introduction into quantitative analysis of groundwater flow and solute transport. It is focussed on understanding, formulating, and solving groundwater flow and solute transport problems. Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems. Students are able to formulate simple, practical groundwater flow and solute transport problems. c) Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change. The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.
This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will also acquire a good understanding of atmospheric environmental problems including air pollution, tropospheric ozone depletion) as well as regional (e.g. urban air pollution) environmental problems.

Objective

Ability to (1) understand the causes and consequences of water scarcity and water pollution problems in large international river systems; (2) understand ways and means of addressing such water challenges; and (3) analyse when and why international efforts in this respect succeed or fail.

Abstract

This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Literature

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Prerequisites

Students are also welcome. The course is open to Master and PhD students from any area of ETH. ISTP students who take this course should also register for the course 860-0012-01L - Cooperation and conflict over international water resources; In-depth case study.

Prerequisites

The definition of prerequisites is part of the admission procedure for the master studies. You are informed by the admission office as to what courses of the section «prerequisites» you have to catch up with. You are accredited for these courses in the electives block of the master studies.

Number |
Title |
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701-0471-01L |
Atmospheric Chemistry |

Abstract

The lecture provides an introduction to atmospheric chemistry at bachelor level. It introduces the fundamentals of gas phase reactions, the concept of solubility and reactions in aerosols and in clouds. It explains the chemical and physical processes responsible for global (e.g. stratospheric ozone depletion) as well as regional (e.g. urban air pollution) environmental problems.

Objective

The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will understand the most important chemical processes in the troposphere and the stratosphere. The students will also acquire a good understanding of atmospheric environmental problems including air pollution, tropospheric ozone formation, stratospheric ozone destruction and the relationship between air pollution and climate change.
The students are able to

- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain how mountains influence the atmospheric flow on different scales
- to explain what processes are responsible for the role of moist adiabatic processes for weather systems in general
- to understand how stable water isotopes are useful in this context

Students also learn to classify radiosonde data, to use the thermodynamic chart (tephigrams) and to identify cloud base, cloud top, and available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed. With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

The lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture.

On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solutions. Participation is recommended.

701-0473-00L Weather Systems W 3 credits 2G M. A. Sprenger, F. Scholder-Aemisegger

Abstract
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Objective
The students are able to
- explain the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain how mountains influence the atmospheric flow on different scales
- to explain what processes are responsible for the role of moist adiabatic processes for weather systems in general
- to understand how stable water isotopes are useful in this context

701-0475-00L Atmospheric Physics W 3 credits 2G U. Lohmann

Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

Objective
Students are able
- to explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

Content
The course starts with introducing selected concepts of thermodynamics for atmospheric processes. The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayton equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to classify radiosonde data, to use the thermodynamic chart (tephigrams) and to identify cloud base, cloud top, and available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed. With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

The lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture.

On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solutions. Participation is recommended.

701-0461-00L Numerical Methods in Environmental Sciences W 3 credits 2G C. Schär, C. Zeman

Abstract
This lecture imparts the mathematical basis necessary for the development and application of numerical models in the field of Environmental Science. The lecture material includes an introduction into numerical techniques for solving ordinary and partial differential equations, as well as exercises aimed at the realization of simple models.

This lecture imparts the mathematical basis necessary for the development and application of numerical models in the field of Environmental Science. The lecture material includes an introduction into numerical techniques for solving ordinary and partial differential equations, as well as exercises aimed at the realization of simple models.
Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. A hands-on approach will be emphasized rather than abstract concepts.

### Numerical Modelling in Fortran

**Abstract**

This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. A hands-on approach will be emphasized rather than abstract concepts.

**Objective**

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

**Lecture notes**

See [http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html](http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html)

**Taught competencies**

- Domain A - Subject-specific Competencies: Techniques and Technologies, assessed
- Domain B - Method-specific Competencies: Media and Digital Technologies, assessed
- Problem-solving, assessed

**Content**

- Observational datasets, observation and detection of climate change;
- Underlying physical processes and feedbacks;
- Numerical and statistical approaches;
- Currently available projections.

**Prerequisites / notice**

- Students have only minimal programming experience, for example with MATLAB scripts.
- A hands-on approach will be emphasized rather than abstract concepts.
- The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes.
- Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Python (previous experience not necessary: a Python introduction is given). Example programs and graphics tools are supplied.
The course will develop along the following outline:

- Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.
- Glaciology and hydropower
- Ocean biogeochemical dynamics: "Global Biogeochemical Cycles and Climate" (701-1317-00L)

If you plan to take this course, please contact one of the professors according to your interest.

- atmospheric chemistry (Prof. T. Peter)
- atmospheric dynamics (Prof. H. Wernli)
- atmospheric physics (Prof. U. Lohmann)
- climate modeling (Prof. C. Schär)
- climate physics (Prof. R. Knutti)
- land-climate dynamics (Prof. S. Seneviratne)
- atmospheric circulation (Prof. S. Schemm)
- paleoclimates (Prof. H. Stoll)
- ocean biogeochemical dynamics (Prof. N. Gruber)

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<tr>
<th>Minor in Physical Glaciology</th>
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<th>Number</th>
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<th>Type</th>
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<tr>
<td>101-0289-00L</td>
<td>Applied Glaciology</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>D. Farinotti, A. Bauder, M. Werder</td>
</tr>
</tbody>
</table>

**Abstract**
The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

**Objective**
The objectives of the course are to:

- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

**Content**
The course will develop along the following outline:

- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

**Lecture notes**
Digital lecture handouts will be distributed prior to each class.

**Literature**
Links to relevant literature will be provided during the classes.

**Prerequisites / notice**
Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

**Taught competencies**

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

- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

- Domain C - Social Competencies
  - Project Management: not assessed
  - Communication: not assessed
  - Cooperation and Teamwork: assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed

- Domain D - Personal Competencies
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: assessed

**Course Catalogue of ETH Zurich**
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

### 651-1077-00L

**Quantification and Modeling of the Cryosphere:**

**Dynamic Processes (University of Zurich)**

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

**ECTS:** 3 credits

**Prerequisites / notice:**

High school mathematics and physics knowledge required.

**Objective:**

Knowledge of the most prominent climate-related geomorphological processes and phenomena in high-mountain regions, understanding of primary research challenges.

**Content:**

Erosion and sedimentation by glaciers as a function of topography, englacial temperature, sediment balance, sliding and melt water runoff. Processes and landforms in regions of seasonal and perennial frost (frost weathering, rock falls, debris cones/talus, solifluction, permafrost creep/rock glaciers, debris flows).

**Literature:**

Glacial and periglacial geomorphodynamics in high-mountain regions. Ca. 100 pages.

**Copies/pdf of scientific papers will be distributed during the course references in skript**

**Seminar in Glaciology**

Overview of the most important earth surface processes and landforms in cold regions (regions with glaciers and intense frost) with emphasis on high-mountain aspects. Discussion of present research challenges.

**Lecturers:**

M. Berg, F. Hammes, S. Bouchet, L. Winkel

**Prerequisites / notice:**

Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes

### Minor in Biogeochemistry

#### Number

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<tbody>
<tr>
<td>701-1313-00L</td>
<td>Isotopes and Biomarkers in Biogeochemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>C. Schubert, R. Kipfer</td>
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<tr>
<td>701-1315-00L</td>
<td>Biogeochemistry of Trace Elements</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Voegelin, S. Bouchet, L. Winkel</td>
</tr>
<tr>
<td>701-1341-00L</td>
<td>Water Resources and Drinking Water</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Hug, M. Berg, F. Hammes, U. von Gunten</td>
</tr>
</tbody>
</table>

**Abstract**

The course introduces the scientific concepts and typical applications of tracers in biogeochemistry. The course covers stable and radioactive isotopes, geochemical tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles. The course provides essential theoretical background for the lab course "Isotopic and Organic Tracers Laboratory".

**Objective**

In-depth knowledge of selected topics in Glaciology. Introduction to different types of scientific presentation. Improve ability of the discussion of scientific topics.

**Content**

Geogenic and cosmogenic radionuclides (sources, decay chains); stable isotopes in biogeochemistry (natural abundance, fractionation); geochemical tracers for processes such as erosion, productivity, redox fronts; biomarkers for specific microbial processes.

**Lecture notes**

Copies/pdf of scientific papers will be distributed during the course

**Prerequisites / notice**

Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:

- 651-3561-00L Kryosphäre
- 101-0289-00L - Applied Glaciology
- 651-4101-00L Physics of Glaciers

**Lecturers**

PhD students of Glaciology.

**Prerequisites / notice**

Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

**Content**

The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.

**Objective**

The students are familiar with the chemical characteristics, the environmental behavior and fate, and the biogeochemical reactivity of different groups of trace elements. They are able to apply their knowledge on the interaction of trace elements with geosphere components and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

**Content**

(i) Definition, importance and biogeochemical classification of trace elements. (ii) Key biogeochemical processes controlling the cycling of different trace elements (base metals, redox-sensitive and chalcophile elements, volatile trace elements) in natural and engineered environments. (iii) Abiotic and biotic processes that determine the environmental fate and impact of selected trace elements.

**Lecture notes**

Selected handouts (lecture notes, literature, exercises) will be distributed during the course.

**Prerequisites / notice**

Students are expected to be familiar with the basic concepts of aquatic and soil chemistry covered in the respective classes at the bachelor level (soil mineralogy, soil organic matter, acid-base and redox reactions, complexation and sorption reactions, precipitation/dissolution reactions, thermodynamics, kinetics, carbonate buffer system).

The lecture 701-1315-00L Biogeochemistry of Trace Elements is a prerequisite for attending the laboratory course 701-1331-00L Trace Elements Laboratory, or students must be concurrently enrolled in 701-1315-00L Biogeochemistry of Trace Elements in the same semester.

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Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this lecture is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Lecture notes
Handouts will be distributed

Literature
Will be mentioned in handouts

701-1346-00L Carbon Mitigation

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>N. Gruber</td>
</tr>
</tbody>
</table>

Priority is given to the target groups: Bachelor and Master Environmental Sciences and PhD Environmental Sciences until September 21st, 2021. Waiting list will be deleted October 1st, 2021.

Abstract
Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content
From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Lecture notes
None

Literature
Will be identified based on the chosen topic.

Prerequisites / notice
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

Minor in Global Change and Sustainability

Number | Title | Type | ECTS | Hours | Lecturers |
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>M. Stauffacher, C. E. Pohl, B. Viennis Baptista</td>
</tr>
</tbody>
</table>

Priority is given to PhD students D-USYS.

All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture. The lecture takes place if a minimum of 12 students register for it.

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature
Literature will be made available to the participants.

The following open access article builds a core element of the course:

Further, this collection of tools will be used
https://naturalsciences.ch/topics/co-producing_knowledge

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00): 29 September, 27 October, 10 November, 24 November, 8 December

701-1551-00L Sustainability Assessment

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>P. Krüttli, D. Nef</td>
</tr>
</tbody>
</table>

Priority is given to participants limited to 35.

Waiting list will be deleted October 1st, 2021.

No enrollment possible after October 1st, 2021.

Abstract
The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

Objective
At the end of the course, students:
- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making
The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

Handouts are provided.

Selected scientific articles and book-chapters

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

The UN World Water Development Reports provide a broad overview of the topic: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

Communication

Handouts of the lecture

Cooperation and Conflict Over International Water Resources

The course is open to Master and PhD students from any area of ETH.

Priority for Science, Technology, and Policy MSc.

The UN World Water Development Reports provide a broad overview of the topic: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

This is a research seminar at the Master level. PhD students are also welcome.

The course is structured as follows:

1. Ability to (1) understand the causes and consequences of water scarcity and water pollution problems in large international river systems; (2) understand ways and means of addressing such water challenges; and (3) analyse when and why international efforts in this respect succeed or fail.

2. Ability to apply hedging strategies and evaluate methods of risk management.

3. In-depth case study.

4. Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.

Students are also welcome.

This is a research seminar at the Master level. PhD students are also welcome.

The course is open to Master and PhD students from any area of ETH.

Priority for Science, Technology, and Policy MSc.

The UN World Water Development Reports provide a broad overview of the topic: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

This is a research seminar at the Master level. PhD students are also welcome.

The course is open to Master and PhD students from any area of ETH.

Priority for Science, Technology, and Policy MSc.
Renewable Energy Technologies

A list of relevant literature is available at the chair.

Energy and Climate Systems I

The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1211-01L</td>
<td>Master's Seminar: Atmosphere and Climate 1</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield König, M. A. Wüest</td>
</tr>
<tr>
<td>701-1211-02L</td>
<td>Master's Seminar: Atmosphere and Climate 2</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield König, M. A. Wüest</td>
</tr>
</tbody>
</table>

Prerequisites / notice

1 excursion per semester, 2 case studies, guest speakers for specific topics.
Course Moodle: https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636
The aims of this course are i) to welcome all students to the master program and to ETH, ii) to acquaint students with the faculty teaching in the field of atmospheric and climate science at ETH and at the University of Bern, iii) that the students get to know each other and iv) to assess needs and discuss options for training and education of soft-skills during the Master program and to give an overview of the study options in general.

### Laboratory and Field Courses

The course in the category «lab and field work» are only offered in spring semester.

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4275-00L</td>
<td>Master's Thesis ■</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:
- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

The master programme is supervised by a professor of the D-ERDW or of the Institute for Atmosphere and Climate (IAC, D-USYS), a professor who teaches in the module subjects or a senior scientist who is on the list of "competent leaders of master theses" of the D-ERDW or of the D-USYS (associated with the IAC).


Objective

The master programme will be completed by a master thesis on a topic selected from the subject range of the chosen major programme. Students are to prove their skills in working autonomously on a scientific project.

### Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0412-AAL</td>
<td>Climate Systems</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>S. I. Seneviratne</td>
</tr>
</tbody>
</table>

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

Objective

Students have a basic understanding of the global energy balance, radiation budget, boundary, layer, atmosphere, ocean, biosphere, land-surface coupling, cryosphere, carbon cycle, climate variability, climate of the past and anthropogenic climate change, and they are able to apply this to solve simple quantitative problems and answer qualitative questions.

### Prerequisites / notice

Teaching: Reto Knutti, several keynotes to special topics by other professors

Course taught in german, slides in english

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0471-AAL</td>
<td>Atmospheric Chemistry</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>M. Ammann, T. Peter</td>
</tr>
</tbody>
</table>

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

Objective

The learning target of this lecture is a general overview on the most important processes of atmospheric chemistry and the various problems of the anthropogenic change in the structure of Earth's atmosphere.

Content

- Origin and properties of the atmosphere: structure, large scale dynamics, UV radiation
- Thermodynamics and kinetics of gas phase reactions: enthalpy and free energy of reactions, rate laws, mechanisms of bimolecular and termolecular reactions.
- Tropospheric photochemistry: Photolysis reactions, photochemical C3 formation, role and budget of H0x, dry and wet deposition
- Aerosols and clouds: chemical, primary and secondary aerosol sources, phase transfer kinetics, solubility and hygroscopicity, N2O5 chemistry, SC2 oxidation, secondary organic aerosols
- Air quality: role of planetary boundary layer, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Stratospheric chemistry: Chapman cycle, Brewer-Dobson circulation, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Global aspects: global budgets of ozone, methane, CO and NOx, air quality - climate interactions

Prerequisites / notice

Basic courses in chemistry and physics are expected

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0475-AAL</td>
<td>Atmospheric Physics</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>U. Lohmann</td>
</tr>
</tbody>
</table>

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

Prerequisites / notice

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

Abstract

This is a self-study course targeted at Master students who did not follow the bachelor course "atmospheric chemistry" or similar. The course provides a general introduction into atmospheric chemistry.
### Mathematics III: Systems Analysis

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit</th>
<th>Type</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture Notes</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0071-AAL</td>
<td>Mathematics III: Systems Analysis</td>
<td>4 credits</td>
<td>E-</td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>The objective of the objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.</td>
<td>Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Matlab (previous experience not necessary: a Matlab introduction is given). Example programs and graphics tools are supplied.</td>
<td>Introduction to principles of models; one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time</td>
</tr>
</tbody>
</table>
Atmospheric and Climate Science Master - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
This course looks into scientific theories and also empirical. T. Braas, 3S
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings - Understanding of research methods used in the empirical human sciences
Human Intelligence
Lecturers
1 credit
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of
Cognitively Activating Instructions in MINT Subjects
E. Stern
P. Edelsbrunner
2 credits
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching
Thematische Schwerpunkte:
- Get to know cognitively activating instructions in MINT subjects
- Understanding of the research methods used in the empirical human sciences
- Understanding of the role of intelligence in the school
- Understanding of the role of motivation in the school
- Understanding of the role of interindividual differences in the learning ability and their causes: Intelligencetheories, Geschlechtsunterschiede beim Lernen
Lernformen:
Lecture notes
Literature
Prerequisites / notice
This lecture is only apt for students who intend to enrol in the programs "Lehrprediplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.
851-0240-22L Coping with Psychosocial Demands of Teaching (EW4 W DZ) ■ 2 credits 3S U. Markwalder, S. Maurer, S. Peteranderl-Rüschoff
Number of participants limited to 20.
The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.
Abstract
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching
Objective
- (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).
- (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).
851-0242-06L Cognitively Activating Instructions in MINT Subjects ■ W 2 credits 2S R. Schumacher
Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).
Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.
Objective
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction
Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.
851-0242-07L Human Intelligence W 1 credit 1S E. Stern
Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).
Number of participants limited to 30.
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW1)".
Abstract
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.
Objective
- Understanding of research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education
851-0242-08L Research Methods in Educational Science W 1 credit 2S P. Edelsbrunner, T. Braas, C. M. Thurn
Number of participants limited to 30.
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW1)".
Abstract
Literature from the learning sciences is critically discussed with a focus on research methods.
At the first meeting, working groups will be assembled and meetings with those will be set up.
In the small groups, students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

Objective
- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

851-0242-11L Gender Issues In Education and STEM ■ W 2 credits 2S M. Berkowitz Biran, T. Braas, C. M. Thurn
Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).
Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

Objective
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher's work.

Content
Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

Prerequisites / notice
Pre-requisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

Educational Science Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

Abstract
This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

Objective
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

Content
Thematiche Schwerpunkte:
Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Konstruktion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen
Lernformen:

Lecture notes
Folien werden zur Verfügung gestellt.

Literature

Prerequisites / notice
This course is only apt for students who intend to enrol in the programs “Lehrdiplom” or “Didaktisches Zertifikat”. It is about learning in childhood and adolescence.

851-0238-01L Support and Diagnosis of Knowledge Acquisition Processes (EW3) ■
Enrolment only possible with matriculation in Teaching Diploma (except for students of Sport Teaching Diploma, who complete the sport-specific course unit EW3) and for students who intend to enrol in the “Teaching Diploma”.
Prerequisites: successful participation in 851-0240-00L “Human Learning (EW1)”.

Abstract
In this seminar, students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective
The main goals are:
(1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
(2) You have a basic understanding about psychological test theory and can appropriately administer tests.
(3) You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

851-0242-01L Coping with Psychosocial Demands of Teaching (EW4) ■
Enrolment possible with Teaching Diploma matriculation, except for students of Sport Teaching Diploma, who complete the sport-specific course unit EW4.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0238-01L</td>
<td>Support and Diagnosis of Knowledge Acquisition Processes (EW3)</td>
<td>O</td>
<td>3 credits</td>
<td>3S</td>
<td>P. Edelsbrunner, J. Maue, C. M. Thurn</td>
</tr>
<tr>
<td>851-0242-01L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4)</td>
<td>O</td>
<td>3 credits</td>
<td>3S</td>
<td>U. Markwalder, S. Maurer, S. Peteranderl-Rüschoff</td>
</tr>
</tbody>
</table>
Understanding research methods used in the empirical human sciences

Students learn and practice techniques and skills for coping with psychosocial demands of teaching.

R. Schumacher

Cognitively Activating Instructions in MINT Subjects

The focus of all classes on educational psychology is on scientific insights which help to reflect on instructional learning. In order to...
### Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:

- **1 credit**

1. **Formation of Knowledge in STEM Fields in Primary**
   - Understand research methods used in the empirical educational sciences
   - Future teachers will learn to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

   **Content**
   - Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:
     - Forest Soil: The soil in the focus of the climate
     - Photosynthesis/Climate change: The tracks in the forest

   **Objective**
   - Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

### 851-0229-00L Using Outdoor Education

**Number of participants limited to 40.**

**Abstract**
In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.

**Objective**
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

**Content**
- Photosynthesis/Climate change: The tracks in the forest
- Forest Soil: The soil in the focus of the climate

**Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.**

### 851-0204-08L Using Outdoor Education

**Number of participants limited to 30.**

**Abstract**
Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

**Objective**
- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

**Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).**

**Prerequisite:** students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

### 851-0242-08L Gender Issues In Education and STEM

**Number of participants limited to 30.**

**Abstract**
In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.

**Objective**
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher's work.

**Content**
- Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

**Prerequisite:** Successful participation in the course 851-0240-00L Human Learning (EW1).

### 851-0240-27L Supervising and Assessing Matura Theses

**Number of participants limited to 20.**

**Abstract**
This course prepares prospective teachers to supervising and assessing scientific projects at upper secondary school level, particularly Matura theses in STEM subjects at Gymnasium.

**Objective**
1. Assessing the adequacy of Matura thesis topics and defining the scope of a project.
2. Determining and promoting a successful work process.
3. Devising and applying criteria for assessing process, product and presentation of a Matura thesis.

**Prerequisite:** successful participation in 851-0240-00L "Human Learning (EW1)."

### 851-0228-00L Formation of Knowledge in STEM Fields in Primary and Secondary School

**Enrolment only possible with matriculation in Teaching Diploma (excluding Teaching Diploma Sport).**

**Abstract**
The event includes a block seminar as well as an assistance period in a primary or secondary school. It is part of a project with the goal of an exchange of expertise: ETH LD students assist primary and secondary school teachers in STEM lessons.

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

**Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.**
To be able to perceive the special situation of the vocational learners in their double burden of occupation and school and to take it into account pedagogically.

LD students learn more about potentials and deficits of students. They get to know better the early stages of knowledge as well as the formation of misconceptions of students in their subject area. The seminar with assistantship includes three phases: In the block seminar misconceptions in the own subject as well as theoretical inputs from developmental and cognitive psychology are discussed (takes place partially in English). During the assistantship, a teaching task defined by the primary and secondary teachers is actively taken on in a class.

At the end there is the writing of a final report, which includes the description of the knowledge level of the students. This seminar is only suitable for LD students who can flexibly adapt to the needs of students from lower grades.

### Compulsory Elective Courses Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0237-01L</td>
<td>Vocational Schools as Sites of Teaching and Learning W 1: Teaching Structure (University of Zürich)</td>
<td>3 credits</td>
<td>2S</td>
<td>University lecturers</td>
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<tr>
<td></td>
<td>Enrolment only possible with Teaching Diploma matriculation.</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: 090LLB1 (ATTENTION: Students of Sport Teaching Diploma enroll in course 090LLB1S)</td>
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<tr>
<td></td>
<td>Simultaneous enrolment in course &quot;Lehr- und Lernort Berufsfachschule II: Förderung und Unterstützung von Lernenden&quot; (UZH Module Code: 090LLB2) is compulsory.</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<td><a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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<td></td>
<td>(&quot;Registering for studies at more than one university, Teaching Diplom&quot;, Philosophische Fakultät)</td>
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<tr>
<td>Objective</td>
<td>&quot;The Vocational Schools as Sites of Teaching and Learning - Teaching Structure&quot; sets out and discusses how to implement the specifications in the framework curriculum. This module is aimed at teachers in high schools awarding vocational school-leaving certificates (Berufsmatura) and all types of vocational schools. It also covers the link established with the company as a learning location.</td>
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<td></td>
<td>- Formulating learning objectives at different levels, and implementing and monitoring these.</td>
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<td>- Steering tuition in terms of content and method to fit in with the objectives.</td>
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<td></td>
<td>- Formulating examination questions and assignments on the basis of the learning objectives set out in the curriculum and the teaching given.</td>
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<td>- Selectively deploying different examination types and procedures/structuring selected learning contents logically in terms of the subject matter and learning process (from the concrete to the abstract, from the simple to the complex) and implementing these with different didactic visual aids.</td>
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<tr>
<td>Content</td>
<td>In der Veranstaltung werden die Rahmen- und Schullehrpläne der Berufsmaturität (alle Richtungen) analysiert und deren Fachinhalt in Übungen und Hospitationen didaktisch umgesetzt. Der Unterricht an der Berufsmaturität wird im Hinblick auf die Herausforderung &quot;Viel Stoff-wenig Zeit&quot; erarbeitet.</td>
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<tr>
<td>Lecture notes</td>
<td>Von den Dozierenden.</td>
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<tr>
<td>Literature</td>
<td>Unterrichten an Berufsfachschulen: Berufsmaturität. hep Verlag Bern</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Die Lehrveranstaltung ist seit September 2008 vom Bundesamt für Berufsbildung und Technologie akkreditiert.</td>
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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0237-02L</td>
<td>Vocational Schools as Sites of Teaching and Learning W 2: Providing Encouragement &amp; Support (UZH)</td>
<td>3 credits</td>
<td>2S</td>
<td>University lecturers</td>
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<td></td>
<td>Enrolment only possible with Teaching Diploma matriculation.</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: 090LLB2</td>
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<td></td>
<td>Simultaneous enrolment in course &quot;Lehr- und Lernort Berufsfachschule I: Unterrichtsgestaltung&quot; (UZH Module Code: 090LLB1) is compulsory.</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<tr>
<td>Abstract</td>
<td>The module &quot;vocational schools as sites of teaching and learning: providing encouragement and support for apprentices&quot; aims to provide teachers at VET and professional baccalaureate institutions with ways of dealing with learners problems, particularly in connection with their being fed up with school, with job-seeking, school-to-work transition, or continuing education.</td>
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<tr>
<td>Objective</td>
<td>- To be able to perceive the special situation of the vocational learners in their double burden of occupation and school and to take it into account pedagogically.</td>
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<td></td>
<td>- Know the transfer topic with regard to performance motivation. Be able to deal with conflicts, disorders and generally difficult situations in BM lessons in a solution-oriented way.</td>
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<td>- Know the forms of company learning and make them usable for teaching.</td>
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<td>- Diagnose crisis developments and take supportive measures.</td>
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<td>- Know the essential aspects of a support-oriented teaching management.</td>
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<td>- Finding role security as a teacher and defining its limits.</td>
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<td></td>
<td>- Gain insights into the concrete training situation of vocational learners.</td>
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</tbody>
</table>
**Cognitively Activating Instructions in MINT Subjects**

*Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).*

- This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)."

*Objective*
- To get to know cognitively activating instructions in MINT subjects
- To get information about recent literature on learning and instruction

*Prerequisites / notice*
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Semesters</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td>851-0229-00L</td>
<td>Using Outdoor Education</td>
<td>1</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
</tr>
<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>1</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
</tr>
<tr>
<td>851-0242-11L</td>
<td>Gender Issues In Education and STEM</td>
<td>2</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
</tr>
</tbody>
</table>

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**Lecture notes**
Handouts vom Dozenten und Sammlung von Arbeitsmaterialien auf dem BSCW-Server.

**Literature**

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**Prerequisites / notice**
- Besonders für die Berufsbildung und Technologie akkreditierte Lehrveranstaltung.
- Keine Vorüberlegung erforderlich.
- Die Lehrveranstaltung ist seit September 2008 vom Bundesamt für Berufsbildung und Technologie akkreditiert.

---

We learn from our mistakes, or rather, we hope that we do. Another way to say this is that we can learn from failure. But, what does "failure" mean? And, what, how, and why do we learn from failure? This course covers research from the cognitive, educational, and learning sciences that addresses the role of failure in human learning. Students will critically examine how failure affects thinking, knowledge, creativity, problem-solving, and motivation.

Objective
- To critically read and analyze articles on research that addresses failure in learning
- Participate in in-class problem-solving activities around research in failure
- Discuss and reflect upon topics in both online and face-to-face formats
- Engage in activities through the online platform
- Complete a final paper on a subtopic related to failure in learning

By the end of the course, the students should be able to:
- Demonstrate a critical understanding of the role that failure plays in learning
- Discuss how and why failure can benefit learning
- Discuss how and why failure does not facilitate learning
- Apply understanding to a related sub-topic

Content
We learn from our mistakes, or rather, we hope that we do. Another way to say this is that we can learn from failure. But, what does "failure" mean? What, how, and why do we learn from failure? This course covers research from the cognitive, educational, and learning sciences that addresses the role of failure in human learning. Students will critically examine how failure affects development of knowledge, creativity, problem-solving, and general thinking and learning. More specifically, they will have the opportunity to question and evaluate the potential relationships between the facets around failure within individual, interactional, cultural, societal, and global contexts through seminal readings and problem-solving activities. Students from any discipline are welcome to this course to learn more about how failure can be harnessed to improve our knowledge, capabilities, innovations, teamwork, and contribute to the larger global world.

The course is held as 2 separate courses with each a maximum of 30 students: one course in German and one course in English.
### Civil Engineering (General Courses)

#### Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-1187-00L</td>
<td>Colloquium in Structural Engineering</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>W. Kaufmann, E. Chatzi, A. Frangi, B. Stojadinovic, B. Sudret, A. Taras, M. Vassiliou</td>
</tr>
</tbody>
</table>

**Abstract**
Professors from national and international universities, technical experts from the industry as well as research associates of the institute of structural engineering (IBK) are invited to present recent research results and specific projects from the practice. This colloquium is addressed to members of universities, practicing engineers and interested persons in general.

**Objective**
Learn about recent research results in structural engineering.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-1387-00L</td>
<td>Colloquia in Geotechnics</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>A. Puzrin, G. Anagnostou, I. Anastasopoulos</td>
</tr>
</tbody>
</table>

**Abstract**
The Institute for Geotechnical Engineering invites distinguished speakers from research and practice, nationally and internationally. The colloquia are directed towards staff and students from Universities as well as engineers and scientists working in industry. Details can be obtained from www.igt.ethz.ch by following Events & Public Events. Some colloquia are available via webcast.

**Objective**
Learn about recent research results in geotechnics.

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### Civil Engineering (General Courses) - Key for Type

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

#### Key for Hours

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

**ECTS**
European Credit Transfer and Accumulation System

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

### First Year Compulsory Courses

In place of the German course 851-0703-03L Private Construction Law students can take the French course 851-0709-00L Introduction to Civil Law.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0241-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>7 credits</td>
<td>5V+2U</td>
<td>M. Akveld</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Mathematical tools for the engineer</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Wird auf der Vorlesungshomepage zu Verfügung gestellt.</td>
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<td></td>
<td>Urs Stammbach, &quot;Analysis III&quot; (erhältlich im ETH Store); <a href="https://people.math.ethz.ch/~stammb/analysisskript.html">https://people.math.ethz.ch/~stammb/analysisskript.html</a></td>
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</tr>
<tr>
<td>401-0141-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5 credits</td>
<td>3V+1U</td>
<td>M. Akka Ginosar</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to Linear Algebra</td>
<td></td>
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<tr>
<td><strong>Objective</strong></td>
<td>Basic knowledge of linear algebra as a tool for solving engineering problems. Understanding of abstract mathematical formulation of technical and scientific problems. Together with Analysis we develop the basic mathematical knowledge for an engineer.</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Introduction and linear systems of equations, matrices, quadratic matrices, determinants and traces, general vector spaces, linear mappings, bases, change of basis, diagonalization, eigenvalues and eigenvectors, orthogonal transformations, scalar-product, inner product spaces.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecturer will provide course notes.</td>
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<td><strong>Literature</strong></td>
<td>K. Nipp, D. Stoffer, Lineare Algebra, VdF Hochschulverlag ETH</td>
<td></td>
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<tr>
<td></td>
<td>G. Strang, Lineare Algebra, Springer</td>
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<tr>
<td>252-0845-00L</td>
<td>Computer Science I</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>C. Cotrini Jimenez, R. Sasse</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The course covers the basic concepts of computer programming. Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Variables, Typen, Kontrollanweisungen, Prozeduren und Funktionen, Scoping, Rekursion, dynamische Programmierung, vektorisierte Programmierung, Effizienz. Als Lernsprache wird Java eingesetzt.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Calculation with MATLAB will be introduced in the first exercise class.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecturer will provide course notes.</td>
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</tr>
<tr>
<td>151-0501-00L</td>
<td>Mechanics 1: Kinematics and Statics</td>
<td>O</td>
<td>5 credits</td>
<td>3V+2U</td>
<td>E. Mazza</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The understanding of the fundamentals of statics for engineers and their application in simple settings. Grundlagen: Lage eines materiellen Punktes; Geschwindigkeit; Kinematik starrer Körper, Translation, Rotation, Kreiselung, ebene Bewegung; Kräfte, Reaktionsprinzip, innere und äussere Kräfte, verteilte Flächen- und Raumkräfte; Leistung</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Statik: Äquivalenz und Reduktion von Kräftegruppen; Ruhe und Gleichgewicht, Hauptsatz der Statik; Lagerbindungen und Lagerkräfte, Lager bei Balkenträgern und Wellen, Vorgehen zur Ermittlung der Lagerkräfte; Parallele Kräfte und Schwerpunkt; Statik der Systeme, Behandlung mit Hauptsatz, mit Prinzip der virtuellen Leistungen, statisch unbestimmte Systeme; Statisch bestimmte Fachwerke, ideale Fachwerke, Pendelstützen, Knotenbiegungswg, räumliche Fachwerke; Reibung, Haftreibung, Gleitreibung, Gelenk und Lagerreibung, Rollreibung; Seilstatik; Beanspruchung in Stabtragern, Querkraft, Normalkraft, Biege- und Torsionsmoment</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Übungsblätter</td>
<td></td>
<td></td>
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<tr>
<td><strong>Literature</strong></td>
<td>Sayir, M.B., Dual J., Kaufmann S., Mazza E., Ingenieurmechanik 1: Grundlagen und Statik, Springer</td>
<td></td>
<td></td>
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<tr>
<td>651-0032-00L</td>
<td>Geology and Petrography</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>K. Rauchenstein, M. O. Saar</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts. The course consists of weekly lectures and bi-weekly exercises in groups.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Weekly handouts of PPT slides via MyStudies</td>
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</tbody>
</table>

Autumn Semester 2021
Page 159 of 2152
This class introduces students to basic features of construction and real estate law.

**Introduction (most important sources of construction and real estate law), SIA (Swiss Society of Engineers and Architects) Design Engineering Services Contract, SIA-Norm 118 (SIA General Terms and Conditions for Construction Services), liability of designers/civil engineers, construction insurance, property law for civil engineers, sale of land, contaminated sites, statutory mortgage for contractors, public procurement, litigation in construction and real estate, the civil engineer as expert.**

**Lecture notes**

There are ‘Lecture Notes’ (in German) for this course.

---

### Optional Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0501-02L</td>
<td>Mechanics 1: Kinematics and Statics (Colloquium)</td>
<td>Z</td>
<td>0 credits</td>
<td>1K</td>
<td>R. Hopf</td>
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**Abstract**

Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power

Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction

**Objective**

The understanding of the fundamentals of Statics for engineers and their application in simple settings.

**Content**

Basics: Position of a material point; velocity; kinematics of rigid bodies; translation, rotation, planar motion; forces, action-reaction principle, internal and external forces, distributed forces; mechanical power.

Statics: equivalence and reduction of groups of forces; rest and equilibrium; basic theorem of statics; kinematic and static boundary conditions, applications to supports and clamps of rods and beams; procedures for determination of forces at supports and clamps; parallel forces and centre of gravity; statics of systems, solution using basic theorem and using the principle of virtual power, statically indeterminate systems; statically indeterminate truss structures, ideal truss structures, nodal point equilibrium, methods for truss force determination; friction, static friction, sliding friction, friction at joints and supports, rolling resistance; forces in cables; beam loading, force and moment vector.

**Literature**

- Übungsblätter
- Sayir, M.B., Dual J., Kaufmann S., Ingenieurmechanik 1: Grundlagen und Statik, Teubner

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### Compulsory Courses 3. Semester

#### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0243-00L</td>
<td>Analysis III</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>M. Akka Ginosar</td>
</tr>
</tbody>
</table>

**Abstract**

We will model and solve scientific problems with partial differential equations. Differential equations which are important in applications will be classified and solved. Elliptic, parabolic and hyperbolic differential equations will be treated. The following mathematical tools will be introduced: Laplace and Fourier transforms, Fourier series, separation of variables, methods of characteristics.

**Objective**

Learning to model scientific problems using partial differential equations and developing a good command of the mathematical tools that can be applied to them. Knowing the formulation of important problems in science and engineering with a view toward civil engineering (when possible). Understanding the properties of the different types of partial differential equations arising in science and in engineering.

**Content**

Classification of partial differential equations

Study of the Heat equation general diffusion/parabolic problems using the following tools through Separation of variables as an introduction to Fourier Series.

Systematic treatment of the complex and real Fourier Series

Study of the wave equation and general hyperbolic problems using Fourier Series, D’Alembert solution and the method of characteristics.

Laplace transform and it's uses to differential equations

Study of the Laplace equation and general elliptic problems using similar tools and generalizations of Fourier series.

Application of Laplace transform for beam theory will be discussed.

Time permitting, we will introduce the Fourier transform.

---

Lecture notes will be provided

large part of the material follow certain chapters of the following first two books quite closely.


The course material is taken from the following sources:

Stanley J. Farlow - Partial Differential Equations for Scientists and Engineers


Prerequisites / notice

Analysis I and II, insbesondere, gewöhnliche Differentialgleichungen.
A. Puzrin

ECTS

Adaptability and Flexibility

4G

Analytical Competencies

not assessed

Type

5 credits

not assessed

assessed

O

Hours

assessed

not assessed

assessed

- Understanding the response of elastic beam and frame structures

Title

1. Motion of a single particle: kinematics (trajectory, velocity, acceleration), forces and torques, constraints, active and reaction forces, balance of linear and angular momentum, work-energy balance, conservative systems, equations of motion.

2. Motion of systems of particles: internal and external forces, balance of linear and angular momentum, work-energy balance, rigid systems of particles, particle collisions, mass accretion/loss.

3. Motion of rigid bodies in 2D and 3D: kinematics (angular velocity, velocity and acceleration transfer, instantaneous center and axis of rotation), balance of linear and angular momentum, work-energy balance, angular momentum transport, inertial vs. moving reference frames, apparent forces, Euler equations.


5. Introduction to waves and vibrations in deformable elastic bodies: local form of linear momentum balance, waves and vibrations in slender elastic rods.

Lecturers

B. Sudret

The course explores the fundamental principles of Geomechanics and Geotechnical Engineering, with the following objectives:

- Recognition of the basic consequences of the ground construction;
- Understanding of the important fundamental concepts of Soil mechanics and Geotechnical Engineering;
- Independent analysis of the basic geotechnical problems.

Content

- Independent analysis of the basic geotechnical problems.
- Understanding of the important fundamental concepts of Soil mechanics and Geotechnical Engineering;
- Equilibrium, reactions, static determinacy
- Internal forces (normal and shear forces, moments)
- Arches and cables
- Elastic trusses
- Influence lines
- Basics of continuum mechanics
- Stresses in elastic beams
- Deformations in Euler-Bernoulli and Timoshenko beams
- Energy theorems
- Statically indeterminate systems (Force method)

Lecture notes

Bruno Sudret, “Einführung in die Baustatik” (2018)

Additional course material will be available on the web page:
https://sudret.ibk.ethz.ch/education/baustatik.html

Literature


➡️ Examination Block 2

Number  Title  Type  ECTS  Hours  Lecturers
101-0113-00L Theory of Structures I  O  5 credits  3V+2U  B. Sudret

Abstract

Introduction to structural mechanics, statically determinate beams and frame structures, trusses, stresses and deformations, statically indeterminate beams and frame structures (force method)

Objective

- Understanding the response of elastic beam and frame structures
- Ability to correctly apply the equilibrium conditions
- Understanding the basics of continuum mechanics
- Computation of stresses and deformations of elastic structures
- Ability to apply the force (flexibility) method for statically indeterminate structures

Content

- Equilibrium, reactions, static determinacy
- Internal forces (normal and shear forces, moments)
- Arches and cables
- Elastic trusses
- Influence lines
- Basics of continuum mechanics
- Stresses in elastic beams
- Deformations in Euler-Bernoulli and Timoshenko beams
- Energy theorems
- Statically indeterminate systems (Force method)

➡️ Compulsory Courses 5. Semester

➡️ Examination Block 3

Number  Title  Type  ECTS  Hours  Lecturers
101-0315-00L Geotechnical Engineering  O  5 credits  4G  A. Puzrin

Abstract

The course explores the fundamental principles of Geomechanics and Geotechnical Engineering, with the following objectives:

Objective

The course explores the fundamental principles of Geomechanics and Geotechnical Engineering, with the following objectives:

Content

Overview of stability problems; Bearing capacity of shallow and deep foundations; Soil-foundation interaction; Analysis and design of shallow and deep foundations; Earth pressure on retaining structures; Analysis and design of retaining walls; Excavations: dewatering, analysis and design; Soil improvement; Safety considerations.

Theoretical foundation and constructional features of the design and construction of steel and steel-concrete composite structures. Multi-

Slides, in English, are made available some days before each lecture.

Steel Structures II
-J.-P. Lebet, M. Hirt: Steel Bridges, Conceptual and Structural Design of Steel and Steel-Concrete Composite Bridges, EPFL Press

Students will expand the knowledge acquired during "Steel Structures I" and learn how to apply these skills to the design of more complex building and bridge steel and composite structures. They will acquire the fundamental background for the phenomena of plate buckling and fatigue and learn how to apply it to practical design tasks. In addition, students will learn to appreciate the importance of questions of detailing, fabrication, erection and cost calculation for the effective design of steel and composite structures.

After completion of the year-long course in Steel Structures I-II, students will have at their disposal a wide and detailed set of skills concerning the modern practice for steel and composite structures design and have a deep understanding of its theoretical & scientific background. The examples of scientific and standardisation work provided in the lectures give the students the opportunity to learn about the most current developments and see how these are used to shape the future practice in the structural engineering field.

The lecture Steel Structures II complements the knowledge acquired in part I by providing students with additional theoretical and practical knowledge, e.g. on the design of steel and composite structures against fatigue, plate buckling, as well as on the structural modelling and analysis of more complex building and bridge structures. These more theoretical topics will be exemplified and illustrated by applications to real problems in the design of bridges and multi-storey building structures. Finally, the course will provide detailed insight into aspects pertaining to structural detailing, fabrication, erection and cost estimation for constructional steelwork.

Content overview:
- Structural forms, analysis techniques and modelling of multi-storey buildings and bridges.
- Structural analysis (deformations, internal forces, stresses and strains) in steel-concrete composite girders considering the effects of creep, shrinkage and shear deformations.
- Elastic and plastic longitudinal shear transfer mechanisms and effects
- Plate buckling of unstiffened and stiffened panels
- Fatigue resistance and safe life assessment; phenomenon and design approaches
- Special topics of steel connection design
- Detailing, drafting, fabrication and erection, cost determination in constructional steelwork

Lecture notes
Lecture notes and slides. Worked Examples with summary of theory. Design aids and formula collections. Videos of lectures.

Literature
- J.-P. Lebet, M. Hirt: Steel Bridges, Conceptual and Structural Design of Steel and Steel-Concrete Composite Bridges, EPFL Press
- Stahlbaukalender (various editions), Ernst & Sohn, Berlin
- Special topics of steel connection design
- Fatigue resistance and safe life assessment
- Fatigue phenomena and design approaches
- Fatigue phenomena and design approaches
- Fatigue phenomena and design approaches
- Fatigue phenomena and design approaches

Prerequisites / notice
The content of steel structures I is a prerequisite

Public Transport and Railways
- J. Nash, H. Orth, S. Schranil

Fundamentals of public and collective transport, in its different forms. Categorization of performance dimensions of public transport systems, and their implications to their design and operations.

Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies. Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders.

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.

Fundamentals: Infrastructures and vehicle technologies of public transport systems; interaction between track and vehicles; passengers and goods as infrastructure users; management and financing of networks.

Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

Vehicles: Classification, design and suitability for different goals

Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

Lecture notes
Lecture notes

Slides, in English, are made available some days before each lecture.

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahninfrastruktur: System- und Netzplanung
The world’s growing population, changing demographics, and changing climate pose formidable challenges to humanity’s ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth’s growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e., ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.

The weekly lectures are structured as follows:
1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems. A high-level overview of the main principles of System Engineering. An introduction to the example that we will be working with through most of the course. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. Analysis – 1/5 – The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, display, weighting, and expected value.
6. Analysis – 2/5 – The idea behind the supply and demand curves and revealed preference methods.
7. Analysis – 3/5 – The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. Analysis – 4/5 – The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Marginal rates of return and internal rates of return.
9. Analysis – 5/5 – How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Evaluation of solutions – Regardless how sophisticated an analysis is, it requires that decision makers stand back and critically evaluate the results. This week we discuss the aspects of evaluating the results of an analysis.
11. Operations research – 1/4 – Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. This week we discuss linear programming and the simplex method.
13. Operations research – 3/4 – How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
14. Operations research – 4/4 – How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches. The quantitative analyses requires the use of Excel. An introduction to Excel will be provided in one of the help sessions.

Lecture notes
- The lecture materials consist of a script, the slides and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

Literature
- Appropriate literature in addition to the lecture materials will be handed out when required via Moodle.

Prerequisites / notice
This course has no prerequisites.
The course introduces the students to engineering hydrology. It covers first physical hydrology, that is the description and the measurement of hydrological processes (precipitation, interception, evapotranspiration, runoff, erosion, and snow), and it introduces then the basic mathematical models of the single processes and of the rainfall-runoff transformation, thereby including flood analysis.

Knowledge of statistics is a prerequisite. The required theoretical background, which is needed for understanding part of the lectures and managing water resources.

Prerequisites / notice
Knowledge of statistics is a prerequisite. The required theoretical background, which is needed for understanding part of the lectures and performing part of the assignments, may be summarised as follows:

- Elementary data processing: hydrological measurements and data, data visualisation (graphical representation and numerical parameters).
- Frequency analysis: hydrological data as random variables, return period, frequency factor, probability paper, probability distribution fitting, parametric and non-parametric tests, parameter estimation.
The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work and to apply engineering working methods. The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

**Recommended Courses**

No specific courses offered in HS21.

**GESS Science in Perspective**

see GESS Science in Perspective: Language Courses

ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-BAUG.
### Civil Engineering Bachelor - Key for Type

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

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

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Civil Engineering Master

► Master Studies (Programme Regulations 2020)

►► 1. Semester

►►► Seminar Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0007-00L</td>
<td>Project Management for Construction Projects</td>
<td>O</td>
<td>4</td>
<td>3S</td>
<td>J. J. Hoffman</td>
</tr>
</tbody>
</table>

**Abstract**

This course is designed to lay down the foundation of the different concepts, techniques, and tools for successful project management of construction projects.

**Objective**

The goal is that at the end of this course students should have a good understanding of the different project management knowledge areas, the phases required for successful project management, and the role of a project manager. To demonstrate this, students will work in groups in different case studies to apply the concepts, tools and techniques presented in the class.

Two 3 to 4 hours sessions towards the end of the lecture series will introduce a practical project to allow the teams to demonstrate the tools and techniques learned during the semester. The course will have a final quiz that will be graded.

**Content**

The main content of the course is summarized in the following topics:

- Project and organization structures
- Project scheduling
- Resource management
- Project estimating
- Project financing
- Risk management
- Project Reporting
- Interpersonal skills

**Literature**

The slides for the class will be available for download from Moodle at least one day before each class. Copies of all necessary documents will be distributed at appropriate times.

**Prerequisites / notice**

Relevant readings will be recommended throughout the course (and made available to the students via Moodle).

**ECTS**

Participants will come to understand how they can best navigate the design and building process, especially in relation to understanding "Design and Building Process MIBS" is a brief manual for prospective architects and engineers covering the competencies and the presentation of the Project Proposal as well as a final exam (50% exam and 50% project report and presentation). Homework will not be graded but your final report and presentation will consist mostly of your homework assignments consolidated and put in a report and presentation format.

►►► Major Courses

►►►► Major in Construction and Maintenance Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-8011-00L</td>
<td>Building Physics: Theory and Applications</td>
<td>W</td>
<td>4</td>
<td>3V+1U</td>
<td>A. Kubilay, X. Zhou, L. D'Amato, A. Rubin, D. A. Strebel</td>
</tr>
</tbody>
</table>

**Abstract**

Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

**Objective**

The students will acquire in the following fields:

- Indoor and outdoor climate and driving forces.
- Hygrothermal properties of building materials.
- Building envelope solutions and their construction.
- Hygrothermal performance and durability.

**Content**

Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.

**Literature**

The recordings of the lectures are available on the MAP under the link https://ethz.zoom.us (book symbol at the top right).

**Prerequisites / notice**

ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE.

**ZoomLink:** https://ethz.zoom.us/j/66588100789

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**Data:** 14.12.2021 12:41

Autumn Semester 2021
Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
- general introduction of transport, modes, technologies,
- system design and line planning for different situations,
- mathematical models for design and line planning,
- timetabling and tactical planning, and related mathematical approaches,
- operations, and quantitative support to operational problems,
- evaluation of public transport systems.

Content

- Basics for line transport systems and networks
- Passenger/Supply requirements for line operations
- Objectives of system and network planning, from different perspectives and users, design dilemmas
- Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
- Matching demand and modes
- Line planning techniques
- Timetabling principles
- Allocation of resources
- Management of operations
- Measures of realized operations
- Improvements of existing services

Lecture notes

- Lecture slides are provided.

Literature

Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Abstract

Infrastructure Management 1: Process 0 6 credits 3G B. T. Adey

Infrastructure asset management is the process used to ensure that infrastructure provides adequate levels of service for specified periods of time. This course provides an overview of the process, from setting goals to developing intervention programs to analyzing the process itself. It consists of weekly lectures and a group project. Additionally, there is a weekly help session.
There are a large number of efforts around the world to obtain more net benefits from infrastructure assets. This can be seen through the proliferation of codes and guidelines and the increasing amount of research in road infrastructure asset management. Many of these codes and guidelines and much of the research, however, are focused on only part of the large complex problem of infrastructure asset management.

The objective of this course is to provide an overview of the entire infrastructure management process. The high-level process described can be used as a starting point to ensure that infrastructure management is done professionally, efficiently and effectively. It also enables a clear understanding of where computer systems can be used to help automate parts of the process. Students can use this process to help improve the specific infrastructure management processes in the organisations in which they work in the future.

More specifically upon completion of the course, students will
- understand the main tasks of an infrastructure manager and the complexity of these tasks,
- understand the importance of setting goals and constraints in the management of infrastructure,
- be able to predict the deterioration of individual assets using discrete states that are often associated with visual inspections,
- be able to develop and evaluate simple management strategies for individual infrastructure assets,
- be able to develop and evaluate intervention programs that are aligned with their strategies,
- understand the principles of guiding projects and evaluating the success of projects,
- be able to formally model infrastructure management processes, and
- understand the importance of evaluating the infrastructure management process and have a general idea of how to do so.

### Content

The weekly lectures are structured as follows:

1. **Introduction**: An introduction to infrastructure management, with emphasis on the consideration of the benefits and costs of infrastructure to all members of society, and balancing the need for prediction accuracy with analysis effort. The expectations of your throughout the semester, including a description of the project.
2. **Positioning infrastructure management in society**: As infrastructure plays such an integral part in society, there is considerable need to ensure that infrastructure managers are managing it as best possible. A prominent network regulator explains the role and activities of a network regulator.
3. **Setting goals and constraints** – To manage infrastructure you need to know what you expect from it in terms of service and how much you are willing to pay for it. We discuss the measures of service for this purpose, as well as the ideas of quantifiable and non-quantifiable benefits, proxies of service, and valuing service.
4. **Predicting the future** – As infrastructure and our expectations of service from it change over time, these changes need to be included in the justification of management activities. This we discuss the connection between provided service and the physical state of the infrastructure and one way to predict their evolution over time.
5. **Help session 1**
6. **Determining and justifying general interventions** - It is advantageous to be able to explain why infrastructure assets need to be maintained, and not simply say that they need to be maintained. This requires explanation of the types of interventions that should be executed and how these interventions will achieve the goals. It also requires explaining which interventions are to be done if it is not possible to do everything due to for example budget constraints. This week we cover how to determine optimal intervention strategies for individual assets, and how to convert these strategies into network level intervention programs.
7. **Determining and justifying monitoring** - Once it is clear how infrastructure might change over time, and the optimal intervention strategies are determined, you need to explain how you are going to know that these states exist. This requires the construction of monitoring strategies for each of asset. This week we focus on how to develop monitoring strategies that ensure interventions are triggered at the right time.
8. **Converting programs to projects / Analysing projects** – Once programs are completed and approved, infrastructure managers must create, supervise and analyse projects. This week we focus on this conversion and the supervision and analysis of projects.
9. **Help session 2**
10. **Ensuring good information** – Infrastructure management requires consistent and correct information. This is enabled by the development of a good information model. This week we provide an introduction to information models and how they are used in infrastructure management.
11. **Evaluating a well-run organization** – How people work together affects how well the infrastructure is managed. This week we focus on the development of the human side of the infrastructure management organisation.
12. **Describing the IM process** – Infrastructure management is a process that is followed continually and improved over time. It should be written down clearly. This week we will concentrate on how this can be done using the formal modelling notation BPMN 2.0.
13. **Evaluating the IM process** – Infrastructure management processes can always be improved. Good managers acknowledge this, but also have a plan for continual improvement. This week we concentrate on how you can systematically evaluate the infrastructure management process.
14. **Help session 3 and submission of project report.**

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R.

### Literature

- The lecture materials consist of handouts, the slides, and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

### Prerequisites / notice

This course has no prerequisites.

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**Autumn Semester 2021**
Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Domain C - Social Competencies

Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies

Adaptability and Flexibility not assessed
Creative Thinking not assessed
Critical Thinking not assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

101-0517-10L Construction Management for Tunneling W 3 credits 2G H. Ehrbar

Abstract
- Construction methods for conventional tunneling in loose material and in hard rock conditions (tunnel, shaft and cavern construction)
- Construction methods for mechanical excavation
- Decision criteria for the selection of tunneling method
- Construction facilities, logistics and construction management

Objective
Transfer of practical knowledge regarding
- Selection of tunneling methods
- Execution and working cycles in conventional and mechanical tunneling
- Management of the muck and of materials
- Quality control and monitoring during construction
- Occupational health and safety requirements and environmental requirements
- Maintenance

The students will be enabled to work on an underground construction project in the preliminary and final design phase as a planner (taking into account contractor's considerations).

Content
General basics
- Codes SIA 196, SIA 197, SIA 198, SIA 118/198
- Knowledge of the tunneling methods
- Decision-making principles for the selection of the tunneling method
- Construction site logistics (transport, ventilation, cooling, water, material management)
- Construction materials

Conventional tunneling
- Excavation methods (full breakout / partial breakout)
- Rock support
- Impermeabilisation
- Inner lining

Mechanical tunneling
- Open TBM (Gripper TBM), rock support concepts
- Shield TBM's in rock and loose ground

Inner lining
- Impermeabilisation and drainage
- Inner lining
- Cable ducts

Lecture notes
Charts of the lecture and references

Literature
References to the usual specialist literature will be made in the course of the lecture

101-0524-00L Lean, Integrated and Digital Project Delivery W 4 credits 3G D. Hall

Abstract
This course is an introduction to innovative construction project delivery through three strategies: integrated information, integrated organization, and integrated processes. Students will be introduced to project and production management concepts such as Lean Construction, Building Information Modeling, the Tri-Constraint Method, & Integrated Project Delivery.

Objective
By the end of the course, students will be able to plan and manage the lean, integrated, and digital project delivery of a construction project.

1. Apply the fundamental theories of lean production to the context of construction management. This includes the ability to describe the three views of production: transformation, flow and value generation; evaluate the benefits of a pull production system compared to push production systems; evaluate how production variability and uncertainty contributes to work-in-process and 'waste'; and apply the concepts of lean production to several construction management tools including the Last Planner System, Pull Planning, Target Value Design, and Takt Planning.

2. Understand the fundamentals of Virtual Design and Construction and Building Information Modeling. This includes the ability to prepare a model breakdown structure capable of integrating project information for all stakeholders; describe the upcoming transition to a common data environment for BIM that will use platforms such as Autodesk Forge; and describe the barriers to successful implementation of BIM within construction and design firms.

3. Plan and schedule an integrated '3D' scope schedule cost model using the Tri-Constraint Method. This includes the ability to understand the TCM algorithm, apply parametric logic to the creation of a virtual model for construction production; and evaluate the limitations of the critical path method when compared to resource- and space-constrained scheduling.

4. Evaluate benefits of integrated project governance compared to the organization of traditional construction project delivery systems. This includes the ability to evaluate the risks, benefits and considerations for integrated teams using multi-party relational contracts that cross disciplinary and firm boundaries; and explain to others the 'elements' of integrated projects (e.g. colocation, early involvement of key stakeholders, shared risk/reward, collaborative decision making).
The construction industry is continually seeking to deliver High-Performance (HP) projects for their clients. HP buildings must meet the criteria of four focus areas – buildability, operability, usability, and sustainability. The project must be buildable, as measured by metrics of cost, schedule, and quality. It must be operable, as measured by the cost of maintaining the facility for the duration of its lifecycle. It must be usable, enabling productivity, efficiency and well-being of those who will inhabit the building. Finally, it must be sustainable, minimizing the use of resources such as energy and water. Buildings that succeed in all four of these areas can be considered HP projects. HP buildings require the integration of building systems. However, the traditional methods of planning and construction do not use an integrated approach. Project fragmentation between many stakeholders is often cited as the cause of poor project outcomes and the reason for poor productivity gains in the construction industry. In response, the construction industry has turned to new forms of integration in order to integrate the processes, organization, and information required for high performance projects.

This course investigates emerging trends in the construction industry – e.g. colocation, shared risk/reward contracts, lean construction methods, and use of shared building information models (BIM) for virtual design and construction (VDC) – as a way to achieve HP projects. For integrated processes, students will be introduced to the fundamentals of lean construction management. This course will look at the causes of variability in construction production and teach the theory of lean production for construction. Processes and technologies will be introduced for lean management, such as the last planner system, just time time planning, production tracking, and target value design. For integrated information, students will be introduced to the fundamentals of virtual design and construction, including how to use work breakdown structures and model breakdown structures for building information modeling, and the fundamentals and opportunities for 4D scheduling, clash detection, and “5D and 6D” models. Future technologies emerging to integrate information such as the use of Autodesk Forge will be presented. Students will have the opportunity to discuss barriers in the industry to more advanced implementation of BIM and VDC.

For integrated organization, students will study the limitations of the construction industry to effectively organize for complex projects, including the challenges of managing highly interdependent tasks and generating knowledge and learning within large multi-organizational project teams. One emerging approach in North America known as IPD will be studied as a case example. Students will explore the benefits of certain ‘elements’ of IPD such as project team colocaiton, early involvement of trade contractors, shared risk/reward contracts, and collaborative decision making.

The course will also include several guest lectures from industry experts to further demonstrate how these concepts are applied in practice.

The class will be presented in a "flipped classroom" environment where students will be required to do readings or watch video before class. In-class activities will act to reinforce and expand upon these primary concepts.

If possible due to COVID restrictions, students will be expected to attend a half-day workshop on the Last Planner System. The date of this workshop will be provided at a later point in time.

The course will also include several guest lectures from industry experts to further demonstrate how these concepts are applied in practice.

This course provides an introduction to the notion of sustainable development when applied to our built environment. In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. In 2016, other political bodies made these changes more difficult to predict. This course provides an introduction to the notion of sustainable development when applied to our built environment. At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmental aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction. After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.
The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world

- Synthesis: Transition to sustainable development

Lecture notes
All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

### Major in Geotechnical Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0317-00L</td>
<td>Tunnelling I</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>G. Anagnostou, E. Pimentel</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement), Numerical analysis methods.</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Content</td>
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<td>Numerical analysis methods in tunnelling. Conventional excavation methods (full face, top heading and bench, side drift method, ...) Auxiliary measures: - Injections - Jet grouting - Ground freezing - Drainage - Forepoling - Face reinforcement</td>
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<td></td>
<td>Lecture notes</td>
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<td>Autographieblätter</td>
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<tr>
<td></td>
<td>Literature</td>
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<td>Empfehlungen</td>
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<td></td>
<td>Taught competencies</td>
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<td>Domain A - Subject-specific Competencies</td>
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<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
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<td></td>
<td>Decision-making</td>
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<tr>
<td>101-0357-00L</td>
<td>Theoretical and Experimental Soil Mechanics</td>
<td>W+</td>
<td>6 credits</td>
<td>4G</td>
<td>I. Anastasopoulos, R. Herzog, E. Korre, A. Marin, M. Schneider</td>
</tr>
<tr>
<td></td>
<td>Prerequisites: Mechanics I, II and III.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Overview of soil behaviour</td>
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<td>Explanation of typical applications: reality, modelling, laboratory tests with transfer of results to the practical examples Consolidation theory and typical applications in practice Triaxial &amp; direct shear tests: consolidation &amp; shear, drained &amp; undrained response Plasticity theory &amp; Critical State Soil Mechanics, Cam Clay Application of plasticity theory</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>Extend knowledge of theoretical approaches that can be used to describe soil behaviour to enable students to carry out more advanced geotechnical design and to plan the appropriate laboratory tests to obtain relevant parameters for coupled plasticity models of soil behaviour. A further goal is to give students the wherewithal to be able to select an appropriate constitutive model and set up insitu stress conditions in preparation for subsequent numerical modelling (e.g. with finite elements).</td>
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<tr>
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<td>Content</td>
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<td>Overview of soil behaviour</td>
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<td>Discussion of general gaps between basic theory and soil response Stress paths in practice &amp; in laboratory tests Explanation of typical applications: reality, modelling, laboratory tests with transfer of results to the practical examples Consolidation theory for incremental and continuous loading oedometer tests and typical applications in practice Triaxial &amp; direct shear tests: consolidation &amp; shear, drained &amp; undrained response Plasticity theory &amp; Critical State Soil Mechanics, Cam Clay Application of plasticity theory</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<td>Printed script with web support Exercises</td>
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<tr>
<td></td>
<td>Literature</td>
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<td><a href="http://geotip.igt.ethz.ch/">http://geotip.igt.ethz.ch/</a></td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
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<td>Lectures will be conducted as Problem Based Learning within the framework of a case history Virtual laboratory in support of 'hands-on' experience of selected laboratory tests Pre-requisites: Basic knowledge in soil mechanics as well as knowledge of advanced mechanics Laboratory equipment will be available for 60 students. First priority goes to those registered for the geotechnics specialty in the Masters, 2nd year students then first year students, doctoral students qualifying officially for their PhD status and then 'first come, first served'.</td>
</tr>
<tr>
<td>101-0307-00L</td>
<td>Design and Construction in Geotechnical Engineering</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>I. Anastasopoulos, A. Marin</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>This lecture deals with the practical application of the knowledge gained in the fundamental lectures from the Bachelor degree. The basics of planning and design of geotechnical structures will be taught for the main topics geotechnical engineers are faced to in practice.</td>
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<tr>
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<td>Objective</td>
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<td></td>
<td>Transfer of the fundamental knowledge taught in the Bachelor degree to practical application. Ability to plan and design geotechnical structures based on the state of the art.</td>
</tr>
</tbody>
</table>
Introduction to Swisscode SIA
Foundations and settlements
Pile foundations
Excavations
Slopes
Soil nailing
Reinforced geosystems
Ground improvement
River levees

Lecture notes
Script in the form of chapters and powerpoint overheads with web support (http://geotip.igt.ethz.ch)
Exercises

Literature
Relevant literature will be stated during the lectures

Prerequisites / notice
Pre-condition: Successful examinations (pass) in the geotechnical studies (soil mechanics and ground engineering, each 5 credits) in the Bachelor degree of Civil Engineering (ETH), or equivalent for new students.

The lecture contains at least one presentation from practice.

101-0369-00L Forensic Geotechnical Engineering
W 3 credits 2G A. Puzrin
Prerequisites: successful participation in "Geotechnical Engineering" (101-0315-00L) or an equivalent course.

Abstract
In this course selected famous geotechnical failures are investigated with the following purpose: (a) to deepen understanding of the geotechnical risks and possible solutions; (b) to practice design and analysis methods; (c) to learn the techniques for investigation of failures; (d) to learn the techniques for mitigation of the failure damage.

Objective
In this course selected famous geotechnical failures are investigated with the following purpose: (a) to deepen understanding of the geotechnical risks and possible solutions; (b) to practice design and analysis methods; (c) to learn the techniques for investigation of failures; (d) to learn the techniques for mitigation of the failure damage.

Content
Failure due to the loading history
Failure due to excessive settlements
Failure due to the leaning instability
Bearing capacity failure
Excavation failure
Failure in the creeping landslides
Failure evolution in submarine landslides
Construction in the landslide influence zone
Delayed failure in snow avalanches

Lecture notes
Lecture notes
Exercises

101-0517-10L Construction Management for Tunneling
W 3 credits 2G H. Ehrbar

Abstract
- Construction methods for conventional tunneling in loose material and in hard rock conditions (tunnel, shaft and cavern construction)
- Construction methods for mechanical excavation
- Decision criteria for the selection of tunneling method
- Construction facilities, logistics and construction management

Objective
Transfer of practical knowledge regarding
- Selection of tunneling methods
- Execution and working cycles in conventional and mechanical tunneling
- Management of the muck and of materials
- Quality control and monitoring during construction
- Occupational health and safety requirements and environmental requirements
- Maintenance

The students will be enabled to work on an underground construction project in the preliminary and final design phase as a planner (taking into account contractor's considerations).
This course focuses on the axial, shear, bending and torsion load-deformation response of continuous elastic prismatic structural elements such as rods, beams, shear walls, frames, arches, cables and rings. Additional special topics, such as the behavior of inelastic prismatic structural elements or the behavior of planar structural elements and structures, may be addressed time-permitting.

After passing this course students will be able to:

1. Explain the equilibrium of continuous structural elements.
2. Formulate mechanical models of continuous prismatic structural elements.
3. Analyze the axial, shear, bending and torsion load-deformation response of prismatic structural elements and structures assembled using these elements.
4. Determine the state of forces and deformations in rods, beams, frame structures, arches, cables and rings under combined mechanical and thermal loading.
5. Use the theory of continuous structures to design structures and understand the basis for structural design code provisions.

This is the third course in the ETH series on theory of structures. Building on the material covered in previous courses, this course focuses on the axial, shear, bending and torsion load-deformation response of continuous elastic prismatic structural elements such as rods, beams, shear walls, frames, arches, cables and rings. Additional special topics, such as the behavior of inelastic prismatic structural elements or the behavior of planar structural elements and structures may be addressed if time permits. The course provides the theoretical background and engineering guidelines for practical structural analysis of modern structures.

Electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes the lecture presentations, additional reading, and exercise problems and solutions. Lectures are streamed live and recorded on the ETH Video Portal.

Working knowledge of theory of structures, as covered in ETH course Theory of Structures I (Baustatik I) and Theory of Structures II (Baustatik II) and ordinary differential equations. Basic knowledge of structural design of reinforced concrete, steel or wood structures. Familiarity with structural analysis computer software and computer tools such as Matlab, Mathematica, Mathcad or Excel.

Familiarity with structural analysis computer software and computer tools such as Matlab, Mathematica, Mathcad or Excel.

This course supplements the courses Structural Concrete I and II regarding the analysis and dimensioning of reinforced and prestressed concrete structures. It focuses on limit analysis methods for girders, discs, slabs and shells, particularly regarding their applicability to the safety assessment of existing structures and their computer-aided implementation.

Enhancement of the understanding of the load-deformation response of reinforced and prestressed concrete; refined knowledge of models and ability to apply them to general problems, particularly regarding the structural safety assessment of existing structures; awareness of, and ability to check, the limits of applicability of limit analysis methods; knowledge of models suitable for computer-aided structural design and ability for critical use of structural design software.
Content Fundamentals (structural analysis, theorems of limit analysis, applicability of limit analysis methods); shear walls and girders (stress fields and truss models, deformation capacity, membrane elements with yield conditions and load-deformation behaviour, computer-aided structural design); slabs (equilibrium solutions, yield conditions, shear and punching shear); fibre reinforced concrete (mechanical behaviour, applications); long term effects; fire behaviour.

Lecture notes Lecture notes see: http://www.concrete.ethz.ch


Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Decision-making</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
</tbody>
</table>

Objective

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Abstract

Expand the theoretical background and practical knowledge in the design of steel and composite structures. Special composite construction and detailing: partial connection, serviceability. Fire design. Cold-formed steel design. Crane girders; masts; tanks & silos. Structural glazing and lightweight cable-supported structures.

Objective

In Steel Structures III, students will deepen and expand their theoretical background and practical knowledge of the design and construction of steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as on certain special fields of application of steel structures. Students will learn how to solve complex structural engineering tasks in larger building projects, e.g. through the use and correct design of large-span slim-floor girders and ultra-slim composite columns, or the use of glazing and cable structures as principal load-carrying components. They learn how steel structures behave under fire conditions and how they can be protected and designed accordingly. Finally, students learn about the fundamental aspects governing the design of specialty steel structures, such as thin-walled cold-formed sections, crane girders, masts and storage tanks.

Content

Steel Structures III provides in-depth theoretical background and practical knowledge on advanced design topics in steel and composite structures. The focus of the course lies on design tasks and solutions in modern, multi-storey, steel-framed buildings driven by architectural needs, as well as on certain special fields of application of steel structures. The course discusses the use and design of large-span slim-floor girders and ultra-slim composite columns, as well as the use of glazing and cable structures as principal load-carrying components. The design of steel structures under elevated temperatures (fire conditions) is treated, as well as special topics of design for serviceability. In addition, fundamental concepts of the design of cold-formed steel framed structures are discussed. Finally, the course will give an overview on the design of specialty steel structures, such as crane girders, masts and storage tanks.

Lecture notes Slides and lecture notes. Worked examples. Handouts and formula collections.

Prerequisites / notice Prerequisites: Steel Structures I and II

101-0137-00L Steel Structures III: Advanced Steel and Composite Structures

| 101-0137-00L | Steel Structures III: Advanced Steel and Composite Structures | O | 3 credits | 2G | A. Taras, U. Angst |

Abstract Structural reliability and risk analysis aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Content Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design are discussed. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.
Structural Dynamics and Vibration Problems  

**Abstract**

Fundamentals of structural dynamics are presented. Computing the response of elastic single and multiple DOF structural systems subjected to harmonic, periodic, pulse, and impulse is discussed. Practical solutions to vibration problems in flexible structures under diverse excitations are developed.

**Objective**

After successful completion of this course the students will be able to:

1. Explain the dynamic equilibrium of structures under dynamic loading.
2. Use second-order differential equations to theoretically and numerically model the dynamic equilibrium of structural systems.
4. Compute the dynamic response of structural system to harmonic, periodic, pulse, and impulse excitation using time-history and response-spectrum methods.
5. Use dynamics of structures to identify the basis for structural design code provisions related to dynamic loading.

**Content**

This is a course on structural dynamics, an extension of structural analysis for loads that induce significant inertial forces and vibratory response of structures. Dynamic responses of elastic and inelastic single-degree-of-freedom and multiple-degree-of-freedom structural systems subjected to harmonic, periodic, pulse, and impulse excitation are discussed. Theoretical background and engineering guidelines for practical solutions to vibration problems in flexible structures caused by humans, machinery, wind or explosions are presented.

**Literature**

- S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

**Prerequisites**

Basic course on probability theory and statistics

**Lecture notes**

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

**101-0157-00L Moisture Transport in Porous Media**

**Abstract**

Moisture transport and related degradation processes in porous materials; experimental determination of moisture transport properties; theory and application of pore network model for two-phase transport in porous media; flow in cracked and deformable porous media.

**Objective**

- Basic knowledge of moisture transport and related degradation processes in porous materials
- Knowledge of experimental determination of moisture transport properties
- Knowledge of pore network model and application to two-phase invasion percolation simulation
- Application of knowledge to moisture transport in cracked materials and flow in deformable porous media

**Content**

1. Introduction

   Moisture damage: problem statement, durability
   Applications: building materials, soil science, geoscience

2. Moisture transport: theory and application

   Description of moisture transport
   Determination of moisture transport properties
   Liquid transport in cracked materials, flow and transport in deformable porous media

3. Pore network model: theory and application

   Single- and two-phase pore network model: quasi-static and dynamic
   Application of knowledge to moisture transport in cracked materials and flow in deformable porous media

**Literature**


**101-0157-00L Fibre Composite Materials in Structural Engineering**

**Abstract**

Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented analysed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.

**Objective**

At the end of the course, you shall be able to:

1. Design advanced FRP composites for your structures,
2. To consult owners and clients with necessray testing and SHM techniques for FRP structures,
3. Continue your education as a phd student in this field.

**Content**

Fibre Reinforced Polymer (FRP) composites are increasingly being used in civil infrastructure applications, such as reinforcing rods, tendons and FRP profiles as well as wraps for seismic upgrading of columns and repair of deteriorated structures. The objective of this course is on one hand to provide new generation of engineering students with an overall awareness of the application and design of FRP reinforcing materials for internal and external strengthening (repair) of reinforced concrete structures. The FRP strengthening of other structures such as metallic and timber will also be shortly discussed. On the other hand the course will provide guidance to students seeking additional information on the topic. Many practical cases will be presented analysed and discussed. An ongoing structural health monitoring of these new materials is necessary to ensure that the structures are performing as planned, and that the safety and integrity of structures is not compromised. The course outlines some of the primary considerations to keep in mind when designing and utilizing structural health monitoring technologies. During the course, students will have the opportunity to design FRP strengthened concrete beams and columns, apply the FRP by themselves, and finally test their samples up to failure.
Comprehension and application of basic knowledge of structural timber design including material behaviour especially anisotropy, moisture

The slides of the lecture serve as lecture notes and are available as download.

Lecturers

The lecture series focuses on the physical principles and technical components of relevant systems for an efficient and sustainable

Will be provided during the lecture.

Conceptual design, detailing and structural analysis of multi-storey timber buildings as well as timber roof structures and halls.

1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM: Comsol)
5 On the nature of failure - Physics of damage and fracture
6 Cracks and growth in structures (LEFM and beyond)
7 A practical approach to LEFM with FEM (Abaqus)
8 Introduction to metal plasticity
9 Damage and fracture in heterogeneous materials
10 Mechanics of fatigue
11 Visco-elastic failure
12 Student -Project presentation

Lecture notes

Will be provided during the lecture via moodle.

Literature

A list of relevant literature is available at the chair.

052-0609-00L Energy and Climate Systems I W 2 credits 2G A. Schlüter

Abstract

The first semester of the annual course focuses on physical principles, component and systems for the efficient and sustainable heating, cooling and ventilation of buildings on different scales and the interaction of technical systems with architectural and urban design.

Objective

The lecture series focuses on the physical principles and technical components of relevant systems for an efficient and sustainable climatisation and energy supply of buildings. A special focus is on the interrelation of supply systems and architectural design and construction. Learning and practising methods of quantifying demand and supply allows identifying parameters relevant for design.

Content

1. Introduction and overview
2. Heating and cooling systems in buildings
3. Ventilation

Lecture notes

The slides of the lecture serve as lecture notes and are available as download.

Literature

A list of relevant literature is available at the chair.

101-0617-02L Computational Science Investigation for Material Mechanics W 4 credits 2S D. Kammer, F. Wittel

Abstract

Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage and failure with advanced finite element methods.

Objective

Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly non-linear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. Starting from the failed state, we will investigate potential causes and find the conditions that resulted in failure. For doing so, you will learn how to predict it with the Finite Element Method (FEM). To correctly assess failure, plastic behavior and size effects, originating from the underlying material microstructure, need to be considered. You will learn how to deal with plasticity in FEM and how you can get information from the heterogeneous material scale into your FEM framework.

Content

1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM: Comsol)
5 On the nature of failure - Physics of damage and fracture
6 Cracks and growth in structures (LEFM and beyond)
7 A practical approach to LEFM with FEM (Abaqus)
8 Introduction to metal plasticity
9 Damage and fracture in heterogeneous materials
10 Mechanics of fatigue
11 Visco-elastic failure
12 Student -Project presentation

Lecture notes

Will be provided during the lecture.

Literature

Will be provided during the lecture.

major in Transport Systems

Number Title Type ECTS Hours Lecturers
101-0427-01L Public Transport Design and Operations O 6 credits 4G F. Corman, F. Leutwiler

Abstract

This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system.
Objective
Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
- general introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning, timetabling and tactical planning, and related mathematical approaches
- operations, and quantitative support to operational problems, evaluation of public transport systems.

Content
Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas
Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles
Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes
Lecture slides are provided.

Literature
Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Taught competencies

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

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

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

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

101-0437-00L  Traffic Engineering  O  6 credits  4G  A. Kouvelas

Abstract
Fundamentals of traffic flow theory and control.

Objective
The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

Content
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

Lecture notes
The lecture notes and additional handouts will be provided during the lectures.

Literature
Additional literature recommendations will be provided during the lectures.

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab sessions take place regularly to guide and support students with the applied part of the course.

<table>
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<tr>
<th>Prerequisites / notice</th>
<th>Transport Planning Methods</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>K. W. Axhausen</th>
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The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab sessions take place regularly to guide and support students with the applied part of the course.

Lecture notes
Moodle platform (enrollment needed)

Literature


In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics. Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation. The program is taught in English and we provide 11 different experts/lecturers.

The goal is to understand and explain basics, principles and contexts of the broader air transport industry. Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport.

Ideal foundation for Aviation II - Management of Air Transport.

The lecture is planned as class teaching with live-streaming and recordings.

The course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Overview of the technical characteristics of railway systems
- Knowledge about the design and construction principles of rail vehicles
- Interrelationships between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators
1 Einführung:
1.1 Geschichte und Struktur des Bahnsystems
1.2 Fahrdynamik

2 Vollbahnfahrzeuge:
2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
2.2 Bremsen
2.3 Traktionsantriebssysteme
2.4 Hilfsbetriebe und Komfortanlagen
2.5 Steuerung und Regelung

3 Infrastruktur:
3.1 Fahrweg
3.2 Bahnstromversorgung
3.3 Sicherungsanlagen

4 Betrieb:
4.1 Interoperabilität, Normen und Zulassung
4.2 RAMS, LCC
4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Geplante Exkursionen:
Betriebszentrale SBB, Zürich Flughafen
Reparatur und Unterhalt, SBB Zürich Altstetten
Fahrzeugfertigung, Stadler Bussnang

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent:
Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahinfrastruktur.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies  | Analytical Competencies | assessed |
| Domain D - Personal Competencies        | Critical Thinking      | assessed |

101-0509-00L Infrastructure Management 1: Process

Abstract
Infrastructure asset management is the process used to ensure that infrastructure provides adequate levels of service for specified periods of time. This course provides an overview of the process, from setting goals to developing intervention programs to analyzing the process itself. It consists of weekly lectures and a group project. Additionally, there is a weekly help session.

Objective
There are a large number of efforts around the world to obtain more net benefits from infrastructure assets. This can be seen through the proliferation of codes and guidelines and the increasing amount of research in road infrastructure asset management. Many of these codes and guidelines and much of the research, however, are focused on only part of the large complex problem of infrastructure asset management.

The objective of this course is to provide an overview of the entire infrastructure management process. The high-level process described can be used as a starting point to ensure that infrastructure management is done professionally, efficiently and effectively. It also enables a clear understanding of where computer systems can be used to help automate parts of the process. Students can use this process to help improve the specific infrastructure management processes in the organisations in which they work in the future.

More specifically upon completion of the course, students will
• understand the main tasks of an infrastructure manager and the complexity of these tasks,
• understand the importance of setting goals and constraints in the management of infrastructure,
• be able to predict the deterioration of individual assets using discrete states that are often associated with visual inspections,
• be able to develop and evaluate simple management strategies for individual infrastructure assets,
• be able to develop and evaluate intervention programs that are aligned with their strategies,
• understand the principles of guiding projects and evaluating the success of projects,
• be able to formally model infrastructure management processes, and
• understand the importance of evaluating the infrastructure management process and have a general idea of how to do so.
This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and how urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine the use of Excel. Some students, however, prefer to use Python or R. The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least 14 weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management, with emphasis on the consideration of the benefits and costs of infrastructure to all members of society, and balancing the need for prediction accuracy with analysis effort. The expectations of your throughout the semester, including a description of the project.

2. Positioning infrastructure management in society. As infrastructure plays such an integral part in society, there is considerable need to ensure that infrastructure managers are managing it as best possible. A prominent network regulator explains the role and activities of a network regulator.

3. Setting goals and constraints – To manage infrastructure you need to know what you expect from it in terms of service and how much you are willing to pay for it. We discuss the measures of service for this purpose, as well as the ideas of quantifiable and non-quantifiable benefits, proxies of service, and valuing service.

4. Predicting the future – As infrastructure and our expectations of service from it change over time, these changes need to be included in the justification of management activities. This we discuss the connection between provided service and the physical state of the infrastructure and one way to predict their evolution over time.

5. Help session 1

6. Determining and justifying general interventions - It is advantageous to be able to explain why infrastructure assets need to be maintained, and not simply say that they need to be maintained. This requires explanation of the types of interventions that should be executed and how these interventions will achieve the goals. It also requires explaining which interventions are to be done if it is not possible to do everything due to for example budget constraints. This week we cover how to determine optimal intervention strategies for individual assets, and how to convert these strategies into network level intervention programs.

7. Determining and justifying monitoring – Once it is clear how infrastructure might change over time, and the optimal intervention strategies are determined, you need to explain how you are going to know that these states exist. This requires the construction of monitoring strategies for each of asset. This week we focus on how to develop monitoring strategies that ensure interventions are triggered at the right time.

8. Converting programs to projects / Analysing projects – Once programs are completed and approved, infrastructure managers must create, supervise and analyse projects. This week we focus on this conversion and the supervision and analysis of projects.

9. Help session 2

10. Ensuring good information – Infrastructure management requires consistent and correct information. This is enabled by the development of a good information model. This week we provide an introduction to information models and how they are used in infrastructure management.

11. Ensuring a well-run organization – How people work together affects how well the infrastructure is managed. This week we focus on the development of the human side of the infrastructure management organisation.

12. Describing the IM process – Infrastructure management is a process that is followed continually and improved over time. It should be written down clearly. This week we will concentrate on how this can be done using the formal modelling notation BPMN 2.0.

13. Evaluating the IM process – Infrastructure management processes can always be improved. Good managers acknowledge this, but also have a plan for continual improvement. This week we concentrate on how you can systematically evaluate the infrastructure management process.

14. Help session 3 and submission of project report.

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least 14 credits.

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

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

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

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

This course has no prerequisites.
The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong micro-foundations and allow for precise policy recommendations.

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**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
101-0247-01L | Hydraulic structures II | O | 6 credits | 4G | R. Boes

**Abstract**
Hydraulic structures and their functions within hydraulic systems are treated in this lecture. The basic concepts of their layout and design with regard to economy and safety are provided.

**Objective**
Knowledge of hydraulic structures and their function within hydraulic systems. Skills for the layout and design of hydraulic structures with regard to economy and safety.

**Content**
Weirs: Weir stability, gates, inflatable dams, appurtenant structures, fish up- and downstream passages.
Conduits: Design of headraces, pressure shafts, and penstocks, constructive details and construction.
Power plants: Power house and turbine types, design, structure, construction.
Dams: Types, appurtenant structures (temporary diversions, spillways, bottom and low-level outlets), dam type selection criteria, layout and design of gravity dams, buttress dams, arch dams, rockfill dams with central core or concrete face, measures in the foundation, mass concrete, RCC dams, reservoir sitation and sediment management, dam surveillance.
Artificial reservoirs: Purpose, layout, sealing, appurtenant structures, environmental aspects.

**Lecture notes**
Course slides will be made available to students prior to each class.

**Literature**
Course slides will be made available to students.

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**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
101-0267-01L | Numerical Hydraulics | O | 3 credits | 2G | M. Holzner

**Abstract**
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.

**Objective**
The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

**Content**
The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

**Lecture notes**
Lecture notes, powerpoints shown in the lecture and programs used can be downloaded. They are also available in German.

**Literature**
Given in lecture.

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**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
102-0455-01L | Groundwater I | W | 4 credits | 3G | J. Jimenez-Martinez, M. Willmann

**Abstract**
The course provides a quantitative introduction to groundwater flow and contaminant transport. Understanding of the basic concepts on groundwater flow and contaminant transport processes. Formulation and solving of practical problems.

**Content**
Properties of porous and fractured media, Darcy’s law, flow equation, stream functions, interpretation of pumping tests, transport processes, transport equation, analytical solutions for transport, numerical methods: finite differences method, aquifers remediation, case studies.

**Lecture notes**
Script and collection of problems available.

**Literature**
W. Kinzelbach, R. Rausch, Grundwassermodellierung, Gebrüder Bornträger, Stuttgart, 1995

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**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
101-0258-00L | River Engineering | O | 3 credits | 2G | V. Weitbrecht, I. Schalko, K. Sperger

**Abstract**
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.
At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

In the second part of the lecture, the methods will be explained to quantify the load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

Content

The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

Prerequisites / notice

Recommended lectures:
Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

101-0468-10L Watershed Modelling W 6 credits 4G P. Molnar

Abstract

Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with practical exercises (experiments).

Objective

The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content

The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGis, Q-Gis) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

Lecture notes

There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature

Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Prerequisites / notice

Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGis (Q-Gis).


Abstract

This course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

Objective

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

Content

Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

Part 2 - Developing your own parallel algorithms
- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

Part 3 - Final project
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes

Digital lecture notes, interactive Julia notebooks, online material.

Literature

Links to relevant literature will be provided during classes.
Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (e.g., Matlab, Python, Julia); advanced programming skills are a plus.

Major in Materials and Mechanics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0677-00L</td>
<td>Concrete Technology</td>
<td>W</td>
<td>2</td>
<td>G</td>
<td>F. Constandopoulos, M. Bäuml, G. Martinola, T. Wangler</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>Opportunities and limitations of concrete technology; Commodities and leading edge specialties.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
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<td></td>
<td>Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.</td>
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</tbody>
</table>
|              | **Content**                        |      |      |       | Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:  
- concrete components  
- concrete properties  
- concrete mix design  
- production, transport, casting  
- demoulding, curing and additional protective measures  
- durability  
- standards  
- chemical admixtures  
- alternative binders  
- specialty concretes such as  
- self compacting concrete  
- fiber reinforced concrete  
- fast setting concrete  
- fair faced concrete  
- recycled concrete  
- new research in digital fabrication with concrete |
|              | **Lecture notes**                  |      |      |       | Slides provided for download. |
|              | **Taught competencies**            |      |      |       | Domain A - Subject-specific Competencies  
Concepts and Theories assessed  
Techniques and Technologies assessed  
Domain B - Method-specific Competencies  
Problem-solving assessed  
Communication assessed  
Domain C - Social Competencies  
Cooperation and Teamwork assessed  
Domain D - Personal Competencies  
Creative Thinking assessed  
Critical Thinking assessed |

151-8015-00L  Moisture Transport in Porous Media  W  3  G  J. Carmeliet, L. Fei, J. Huang, J. Zhao

Abstract
Moisture transport and related degradation processes in porous materials; experimental determination of moisture transport properties; theory and application of pore network model for two-phase transport in porous media; flow in cracked and deformable porous media.

Objective
- Basic knowledge of moisture transport and related degradation processes in porous materials  
- Knowledge of experimental determination of moisture transport properties  
- Knowledge of pore network model and application to two-phase invasion percolation simulation  
- Application of knowledge to moisture transport in cracked materials and flow in deformable porous media

Content
1. Moisture transport: theory and application  
Moisture damage: problem statement, durability  
Applications: building materials, soil science, geoscience  

2. Moisture transport: theory and application  
Description of moisture transport  
Determination of moisture transport properties  
Liquid transport in cracked materials, flow and transport in deformable porous media

3. Pore network model: theory and application  
Single- and two-phase pore network model: quasi-static and dynamic  
Exercise on quasi-static two-phase pore network model: invasion pattern, capillary pressure curve  
Application of pore network model in two-phase transport

Lecture notes
Handouts, supporting material and exercises are provided online via Moodle.

Literature
All material is provided online via Moodle.

151-0353-00L  Mechanics of Composite Materials  W  4  2V+1U  P. Ermanni, G. Pappas, M. Sakovsky

Abstract
Focus is on laminated fibre reinforced polymer composites. The courses treats aspects related to micromechanics, elastic behavior of unidirectional and multidirectional laminates, failure and damage analysis, design and analysis of composite structures.

Objective
To introduce the underlying concept of composite materials and give a thorough understanding of the mechanical response of materials and structures made from fibre reinforced polymer composites, including elastic behaviour, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

Content
The course is addressing following topics:  
- Introduction  
- Elastic anisotropy  
- Micromechanics aspects  
- Classical Laminate Theory (CLT)  
- Failure hypotheses and damage analysis  
- Analysis and design of composite structures  
- Variable stiffness structures

Lecture notes
Script, handouts, exercises and additional material are available in PDF-format on the CMASLab webpage resp on moodle.  
https://moodle-app2.let.ethz.ch/course/view.php?id=2610

Literature
The lecture material is covered by the script and further literature is referenced in there.
### Taught competencies

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

**Domain B - Method-specific Competencies**
- **Analytical Competencies**: assessed
- **Decision-making**: assessed
- **Media and Digital Technologies**: not assessed
- **Problem-solving**: assessed
- **Project Management**: not assessed

**Domain C - Social Competencies**
- **Communication**: not assessed
- **Cooperation and Teamwork**: not assessed
- **Customer Orientation**: not assessed
- **Leadership and Responsibility**: not assessed
- **Self-presentation and Social Influence**: not assessed
- **Sensitivity to Diversity**: not assessed
- **Negotiation**: not assessed

**Domain D - Personal Competencies**
- **Adaptability and Flexibility**: not assessed
- **Creative Thinking**: assessed
- **Critical Thinking**: assessed
- **Integrity and Work Ethics**: assessed
- **Self-awareness and Self-reflection**: assessed
- **Self-direction and Self-management**: not assessed

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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Study Mode</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0617-01L</td>
<td>Advances in Building Materials</td>
<td>W 4 credits 2G</td>
<td>R. J. Flatt, I. Burgert</td>
<td></td>
</tr>
<tr>
<td>101-0617-02L</td>
<td>Computational Science Investigation for Material Mechanics</td>
<td>W 4 credits 2S</td>
<td>D. Kammer, F. Wittel</td>
<td></td>
</tr>
</tbody>
</table>

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**Abstract**

**Advances in Building Materials**
The course on Advances in Building Materials provides an introductory overview of the needs and future of materials science in the building sector. Focus topics concern sustainability, durability, thermal insulation, coatings, sealants, adhesives, flame retardancy and the future perspective and developments of concrete and wood with regard to smart material development and ecological concerns.

**Objective**

In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

**Content**

This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges.

The following topics are covered:
1. Material selection
2. Materials and sustainability 1
3. Materials and sustainability 2
4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

**Lecture notes**
Handouts will be provided for each lecture.

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**Abstract**

**Computational Science Investigation for Material Mechanics**
Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage and failure with advanced finite element methods.

**Objective**

Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. Starting from the failed state, we will investigate potential causes and find the conditions that resulted in failure. For doing so, you will learn how to predict it with the Finite Element Method (FEM). To correctly assess failure, plastic behavior and size effects, originating from the underlying material microstructure, need to be considered. You will learn how to deal with plasticity in FEM and how you can get information from the heterogeneous material scale into your FEM framework.

**Content**

1. Introduction to (numeric) forensic engineering
2. The nature of engineering problems (governing equations)
3. Numerical recipes for dealing with non-linear problems
4. Multi-field problems (HTM; Comsol)
5. On the nature of failure - Physics of damage and fracture
6. Cracks and growth in structures (LEFM and beyond)
7. A practical approach to LEFM with FEM (Abaqus)
8. Introduction to metal plasticity
9. Damage and fracture in heterogeneous materials
10. Mechanics of fatigue
11. Visco-elastic failure
12. Student - Project presentation

**Lecture notes**
Will be provided during the lecture via moodle.

**Literature**
Will be provided during the lecture.
All documents for certification labels as well as detail plans of the buildings will be available for the students. Hours

A script will be given out at the beginning of the course. Building labels are used to certify buildings and neighbourhoods in terms of sustainability. Many different labels have been developed and

The course will give Engineering students a comprehensive overview and enduring understanding of the techniques, processes, tools and terminology to manage the Project Triangle (time, cost, Quality) and to organize, analyze, control and report a complex project from start of Project Execution to Project Completion. Responsibilities will be detailed in each phase of the execution. A student after completing the course will have the understanding of the Project Management duties, responsibilities, actions and decisions to be done during the Execution phase of a complex project.

- to use operation research methods to find optimal solutions to infrastructure management problems
- to use preventive maintenance models, such as block replacement, periodic preventive maintenance with minimal repair, and preventive maintenance based on parameter control, to determine when, where and what should be done to maintain infrastructure

Explanation of the principal models of preventative maintenance, including block replacement, periodic group repair, periodic maintenance with minimal repair and age replacement, and when they can be used to determine optimal intervention strategies

The slides from the presentations will be made available.

Number of participants limited to 25

Different certification schemes, including LEED (American standard), DGNB (German Standard with Swiss adaptation), Label SNBS, MINERGIE-ECO and 2000-Watt-Site (Swiss standards) will be presented and explained by experts.

After this overall general presentation and in order to have a closer look to specific aspects of sustainability, students will work in groups and assess during one or two weeks this specific criterion on one of the case studies presented before. This practical hands on the label will end with a presentation and a discussion where we will highlight differences between the labels.

The alternance of working session on one specific criterion for one specific building followed by a group presentation and discussion to compare labels is repeated for the different focus points (operation, energy, mobility, daylight, indoor air quality).

After this overall general presentation and in order to have a closer look to specific aspects of sustainability, students will work in groups and assess during one or two weeks this specific criterion on one of the case studies presented before. This practical hands on the label will end with a presentation and a discussion where we will highlight differences between the labels.

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Content
Execution Phase of the Project
Engineering Management - Scope, EV Measurement, Reporting and Organization
Procurement and Transportation - Scope, EV Measurement, Reporting and Organization
Civil Construction and Erection - Scope, EV Measurement, Reporting and Organization
Financial Reporting and forecasting
Risk & Opportunity Identification Assessment and Quantification during Execution
Team Organization and Leadership
Risk and opportunity identification and quantification
Contract Claims and Delays
Execution Quality

Literature
Required and suggested reading will be uploaded on weakly basis.

Prerequisites / notice
Prerequisite for this course is course Project Management: Pre-Tender to Contract Execution number 101-0517-01 G, unless otherwise approved by the lecturer.

101-0608-00L
Design-Integrated Life Cycle Assessment

W  3 credits  2G  G. Habert

Abstract
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

Objective
The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:
1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

Content
The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:

1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Lecture notes
As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

Prerequisites / notice
Prerequisite: Sustainable construction (101-0577-00L). Otherwise a special permission by the lecturer is required.

The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly the departments ARCH, BAUG, ITET, MAVT, MTEC and UWIS.

No lecture will be given during Seminar week.

101-0577-00L
An Introduction to Sustainable Development in the Built Environment

O  3 credits  2G  G. Habert, D. Kaushal

Abstract
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. In 2016, other political bodies made these changes more difficult to predict. What does it mean for the built environment?

This course provides an introduction to the notion of sustainable development when applied to our built environment

Objective
At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmental aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.
The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world
- Synthesis: Transition to sustainable development

Lecture notes
All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

101-0527-10L  Materials and Constructions  W  3 credits  2G  G. Habert, D. Sanz Pont

Abstract
Building materials with a special focus on regenerative materials: earth, bio-based and reuse.

Objective
Special focus on regenerative materials: earth, bio-based and reuse

Content
Introduction
Sustainable cement and concrete
Earth construction
Visit
Steel and bamboo
Timber construction
Building physic and conventional insulation
Bio-based insulation
Finishing
Reuse

►►► Major in Geotechnical Engineering

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>101-0329-00L</td>
<td>Tunnelling III</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>G. Anagnostou, E. Pimentel, M. Ramoni</td>
</tr>
</tbody>
</table>

Abstract
Deepen the knowledge on selected topics of underground construction as well as learning working out conceptual solutions of complex problems.

Objective
Lecture: Deepen the knowledge on selected topics of underground construction.
Exercises: Conceptual solutions of complex problems.

Content
Caverns: Geometry, construction methods, support.
Shafts: Construction methods, support.
Urban tunnelling: Boundary conditions, system choice, alignment, design.
Field measurements: Principles, monitoring layout, applications, interpretation.
Cut and cover tunnels: Modelling, design.
Exercising conceptual solution of complex tunnelling problems based upon discussion of current tunnel cases with particularly demanding problems in small groups.

Lecture notes
Autographieblätter

Prerequisites / notice
Prerequisite: BSc course "Tunnelling", MSc courses "Tunnelling I" and "Tunnelling II".

101-0339-00L  Environmental Geotechnics  W  3 credits  2G  M. Plötze

Abstract
Introduction of basic knowledge about problems with contaminated sites, investigation of this sites, risque management, remediation and reclamation techniques as well as monitoring systems.
Introduction in landfill design and engineering with focus on barrier- and drainage systems and lining materials, evaluation of geotechnical problems, e.g. stability

Objective
Introduction of basic knowledge about problems with contaminated sites, investigation of this sites, risque management, remediation and reclamation techniques as well as monitoring systems.
Introduction in landfill design and engineering with focus on barrier- and drainage systems as wellas lining materials, evaluation of geotechnical problems, e.g. stability
### Knowledge of the engineering properties of materials for masonry construction.

E. Chatzi  
N. Mojsilovic

**Historical Development of Masonry Construction**

Autographie, Uebungsblätter, Handouts, Folien  
2G  
B. Herraiz Gómez

Structural Masonry  
A. Arêde, H. Varum, Strengthening and Retrofitting of Existing Structures, Springer, 339p, 2018

ECTS  
W

Non Destructive Evaluation & Rehabilitation of Existing Structures  
Swiss Standards SIA 269, 269/1 to 269/7  
Swiss Standards SIA 269, 269/1 to 269/7

Geotechnical Engineering in Transportation  
Swiss Standards SIA 269, 269/1 to 269/7

Geotechnical Engineering in Transportation  
Swiss Standards SIA 269, 269/1 to 269/7

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<tr>
<td>101-0119-00L</td>
<td>Structural Masonry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>N. Mojsilovic</td>
</tr>
<tr>
<td></td>
<td>Knowledge of the engineering properties of materials for masonry construction.</td>
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<td></td>
<td>Technical understanding of the structural behaviour of load-bearing masonry structures subjected to in-plane forces and combined actions.</td>
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<td>Develop a technical competence for design procedures for load-bearing masonry structures by means of exercises.</td>
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<tr>
<td>101-0129-00L</td>
<td>Non Destructive Evaluation &amp; Rehabilitation of Existing Structures</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>E. Chatzi, B. Herraiz Gómez, G. Kocur</td>
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<td></td>
<td>Introduction to non destructive evaluation tools and quantitative structural analyses and verifications for condition assessment of existing structures and subsequent decisions on their rehabilitation.</td>
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<td>The goal is for students to familiarize themselves with the handling of assessment and rehabilitation of existing structures from the perspective of a consulting engineer, following a systematic approach as described in current codes and to further learn how to use new non destructive evaluation technologies.</td>
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<td>This course is organized in two main pillars. The first pillar describes the technologies that are available for non destructive evaluation of structures and delves into description of the principle of operation of such methods (e.g. wave propagation, acoustic emission analysis, tomography). The second pillar, overviews the current implementation of condition assessment processes in codes and standards. Complementary to the topic of structural evaluation, the topic of interventions, rehabilitation and retrofitting of existing structures for different construction materials is next addressed.</td>
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Autumn Semester 2021  
Page 191 of 2152
The Method of Finite Elements II is a continuation of Method of Finite Elements I. Here, we explore the theoretical and numerical implementation concepts for the finite element analysis beyond the linear elastic behavior. This course aims to offer students with the skills to perform nonlinear FEM simulations using coding in Python.

This class overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity. In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

The course specifically covers the treatment of the following phenomena:
- Material Nonlinearity (Plasticity)
- Geometric Nonlinearity (Large Displacement Problems)
- Nonlinear Dynamics
- Fracture Mechanics

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

See the class webpage for more information:

The course slides serve as Script. These are openly available on: http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Useful (optional) Reading:

Prerequisites:
- 101-0158-01, Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

Prerequisites / notice

After successfully completing this course the students will be able to:

1. Understand the mechanics of and design isolator bearings.
2. Understand the dynamics of and design an isolated structure.

Content

1. Introduction: Overview of seismic isolation; review of structural dynamics and earthquake engineering principles. Viscoelastic behavior.
2. Linear theory of seismic isolation
3. Types of seismic isolation devices - Modelling of seismic isolation devices – Nonlinear response analysis of seismically isolated structures in Matlab
4. Behavior of rubber isolators under shear and compression
5. Behavior of rubber isolators under bending
6. Buckling and stability of rubber isolators
7. Code provisions for seismically isolated buildings

Lecture notes

The electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes: reading material, and (optional) exercise problems and solutions.

Literature

There is no single textbook for this course. However, most of the lectures are based on parts of the following books:

- Dynamics of Structures, Theory and Applications to Earthquake Engineering, 4th edition, Anil Chopra, Prentice Hall, 2017
- Design of seismic isolated structures: from theory to practice, Farzad Naeim and James M. Kelly, John Wiley & Sons, 1999
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011

Prerequisites / notice

101-0157-01 Structural Dynamics and Vibration Problems course, or equivalent, or consent of the instructor. Students are expected to know basic modal analysis, elastic spectrum analysis and basic structural mechanics.
Content

The goal of the course is to introduce the civil engineering students to Structural Design, which is understood as a discipline that relates structural behavior, construction technologies and architectural concepts. Hence, the course encourages the students to develop an intuitive understanding of the relationship between the form of a structure and the forces within it by promoting the development of designed projects, in which the static and architectural aspects come together. The course is structured in two main parts, each developed in half of a semester: a mainly theoretical one (including the teaching of graphic statics) and a mainly applied one (focused on the development of a design project by the students using digital form-finding tools).

Theory:

Graphic statics is a graphical method developed by Prof. Karl Culmann and firstly published in 1864 at ETH Zurich. In this approach to structural analysis and design, geometric construction techniques are used to visualize the relation between the geometry of a structure and the forces acting in and on it, represented by geometrically dependent form and force diagrams.

The course will firstly review the main principles of graphic statics through a series of frontal lectures and discuss the relationship to analytical statics. Graphic statics is then used as an operative tool to design structures in equilibrium based on the lower bound theorem of the Theory of Plasticity. Additionally, the course will introduce contemporary methodologies and tools (parametric CAD software) for the interactive application of equilibrium modelling in the form of short workshops. The students will familiarize with the topic by solving exercises and confronting themselves with simple design tasks.

Design Project:

Specific structural design approaches and design methodologies based on graphic statics and references from construction history will be introduced to the students by means of seminars and workshops. By developing a design project, the students will apply these concepts and techniques in order to become proficient with open design tasks (such as the design of a bridge, a large span hall or a tower). At the end of the semester, the students present their projects to a jury of internal and external critics in a final review. The main criterion of evaluation is the students’ ability to integrate architectural considerations into their structural design.

Literature

"Faustformel Tragwerksentwurf"
(Philippe Bataille, Christoph Gengangel, Stefan Peters,

"Form and Forces: Designing Efficient, Expressive Structures"

"The art of structures. Introduction to the functioning of structures in architecture"

101-0121-00L Fatigue and Fracture in Materials and Structures W 4 credits 3G E. Ghafouri, A. Taras

Abstract

The fundamentals in fatigue and fracture mechanics, which are used in different engineering disciplines (e.g., for mechanical, aerospace, civil and material engineers) will be discussed. The focus will be on fundamental theories (based on fracture mechanics) that model fatigue damage and crack propagation.

Objective

In this course, the students will learn:

* Linear elastic and elastic-plastic fracture mechanics.
* Modern computer-based techniques (using ABAQUS Finite Element Package) to simulate cracks in both bulk materials and bonded joints/interfaces.
* Laboratory fatigue and fracture tests on details with cracks.

Content

The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered in this course are:

I) Fatigue of materials:

* Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
* Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner’s damage rule.
* Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

II) Fracture mechanics:

* ELinear elastic fracture mechanics (LEFM): limits of LEFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
* Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
* Fatigue crack growth (FCG): FCG models, Paris’ law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

III) Introduction to cohesive zone models (CZMs):

* Advantages and disadvantages of CZMs compared to fracture mechanics.
* Different bond-slip models for the bonded joints/interfaces.

IV) Computer laboratory to simulate cracks and debonding problems:

* Finite Element (FE) modeling of complex details with cracks.
* FE simulations of debonding problems using CZMs.
* Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

V) Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

VI) Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and “Laboratory Competition”. The students will:

* Visit different small-scale and large-scale fatigue testing equipment.
* Get to know different ongoing fatigue- and fracture-related projects.
* Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
* Compare the experimental results with their own calculations (from the fracture theories).
* “Laboratory Competition” at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded by a prize.

Lecture notes

Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.


Prerequisites / notice
Note 1: A basic knowledge on mechanics of structures and structural analysis (i.e., stress-strain analysis and calculations of internal deformations, strains and stresses within structures) is recommended and will be helpful in the course.

Note 2: Laboratory demonstrations and fatigue/fracture tests at the Structural Engineering Research Laboratory of Empa in Dübendorf. This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Semester</th>
<th>Credits</th>
<th>Lecture / Tutorial</th>
<th>Notes</th>
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<tbody>
<tr>
<td>101-0169-00L</td>
<td>Timber Structures III</td>
<td>W</td>
<td>3</td>
<td>G</td>
<td>A. Frangi, R. Jockwer, M. Klippel, S. M. Schoenwald, R. Steiger</td>
</tr>
<tr>
<td>101-0120-00L</td>
<td>Structural Glass Design and Facade Engineering</td>
<td>W</td>
<td>3</td>
<td>G</td>
<td>V.-A. Silvestru</td>
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<tr>
<td>101-0139-00L</td>
<td>Scientific Machine and Deep Learning for Design and Construction in Civil Engineering</td>
<td>W</td>
<td>3</td>
<td>G</td>
<td>M. A. Kraus, D. Griego</td>
</tr>
</tbody>
</table>

Abstract
Consolidation and supplementation of the basic knowledge acquired in Timber Structures I + II. Treatment of current topics and innovations in timber engineering. Structural design and refurbishment of complex timber structures with high requirements for earthquake resistance, sound insulation and fire protection. Description, analysis and discussion of an existing timber structure in groups.

Objective
In-depth understanding of the theoretical and design aspects of timber construction. Dimensioning, structural design, optimisation and refurbishment of complex timber structures with high requirements for earthquake resistance, sound insulation and fire protection.

Content
Multi-storey timber buildings (general, cross laminated timber, high-rise buildings, fire protection, sound insulation), Post-tensioned timber constructions, building with hardwood, robustness of timber structures, earthquake-resistant timber structures, maintenance and renovation of structures.

Lecture notes
Autography Timber Structures
 Copies of lecture slides

Literature
Timber design tables HBT 1, Lignum
Swiss Standard SIA 265
Swiss Standard SIA 265/1
Eurocode 5

Prerequisites / notice
Timber Structures I + II

Abstract
The course gives an introduction to structural glass design and related façade engineering aspects. It will focus on the properties of the material glass and glass products, as well as on the structural design of glass elements and their supporting systems and connections.

Objective
After successful completion of the course, students will be able to:
- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;
- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;
- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;
- Apply selected approaches for the structural design of in-plane loaded glass elements;
- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.

Content
This course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.

Lectures:
The lectures will cover the following contents:
- Basic principles and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);
- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);
- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);
- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);
- Typologies and design of structural systems for transparent façades;
- Requirements and functions for transparent façades.

Design exercises:
The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.

Design project:
The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.

Lecture notes
The lectures are based on lecture slides and handouts.

Literature
Recommended and supplementary literature:

Prerequisites / notice
Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.

Abstract
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction in civil engineering. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.
Objective

This course aims to provide graduate level introduction into Machine and especially scientific Machine Learning for applications in the design and construction phases of projects from civil engineering.

Upon completion of the course, the students will be able to:
1. understand main ML background theory and methods
2. assess a problem and apply ML and DL in a computational framework accordingly
3. Incorporating scientific domain knowledge in the SciML process
4. Define, Plan, Conduct and Present a SciML project

Content

The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
1. Fundamentals of Machine and Deep Learning (ML / DL)
2. Incorporation of Domain Knowledge into ML and DL
3. ML training, validation and testing pipelines for academic and research projects

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

Lecture notes

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Literature

Suggested Reading:
- Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
- S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016

Prerequisites / notice

Familiarity with MATLAB and / or Python is advised.

-major in transport systems

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0469-00L</td>
<td>Road Safety</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Deublein, P. Eberling</td>
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<tr>
<td>Abstract</td>
<td>The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety Aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.</td>
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<tr>
<td>Objective</td>
<td>Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety</td>
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<tr>
<td>Content</td>
<td>Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy</td>
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<td>103-0417-02L</td>
<td>Methodology of Planning Research and Practice</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Peric Momcilovic, T. Hug, R. Streit</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course deals with scientific and applied methods and the ways of thinking that are useful in planning practice as well as in scientific research. Students are offered interdisciplinary knowledge from planning practice and research, behavioural economics and social sciences. New perspectives on planning are opened up, which can lead to better results in future projects and research.</td>
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<td>Objective</td>
<td>Keeping the general aim of exploring the basic methodologies in spatial planning research and practice, the specific course learning objectives are as follows:</td>
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<td>- to address complex real-world spatial problems in adequate ways</td>
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<td>- to know relevant theories and maxims that are subject to specific methods of problem solving</td>
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<td>- to identify key questions and key concepts in contemporary planning research</td>
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<td>- to select appropriate research methods to properly address the research questions</td>
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<td>In practical terms, students:</td>
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<td>- learn to deal with uncertainties and estimate quantities</td>
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<td>- improve their ability to take decisions based on incomplete data and information</td>
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<td>- are informed about different (qualitative and quantitative) methods and techniques for spatial research</td>
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<td>- learn about different types of research (theoretical, empirical, action-oriented, qualitative, quantitative)</td>
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<td>- get skilled for writing simple research essays</td>
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<td>- are urged to question their own knowledge and challenge the course of action taken in planning processes</td>
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The course is based on the following questions:

How do we deal with complex issues in planning?
- Forms of knowledge, half-knowledge and not knowing
- Occurrence and explanation patterns for irrational behaviour
- Spatial research and planning practice
- Planning maxims
- Mapping complex topics in research questions

How do we generate knowledge about complex issues?
- Methods for scientific data generation
- Applied handling of quantities and probabilities
- Estimating despite uncertainties
- Opportunities of digitisation in planning (Participation, BigData)

How do we react to complex questions in planning?
- Methods of scientific data analysis
- Making decisions despite incomplete information
- Dealing with robustness and fragility

More specifically, the lectures focus on the following topics (NB: Some content units will be presented in English, they are marked with *asterisk below)
- (Half-) knowledge/behaviour/irrationalities
- Initial situation: Solving complex problems
- Behavioural patterns, occurrence and explanation patterns for irrational behaviour
- Methods for solving complex tasks in planning practice
- Spatial research and planning practice - connections, differences, overlaps
- Challenges in the solution of complex tasks: System delimitation, interdisciplinarity, retrospective vs. prospective approach (descriptive vs. action-oriented, "reflected scenario building")
- Planning maxims
- *Methodology in spatial research
- *Research design
- *Research questions (types of research questions; research questions, hypotheses and theories); justification of research question
- Data generation methods (interviews and questionnaires, ethnography and observation, documents, official statistics)
- Dealing with quantities, estimations, anchor effect
- Importance of scales and key figures in planning
- Estimation methods
- Danger of the anchor effect
- Digitalization in planning
- New data sources and sizes
- Opportunities and challenges through digitisation in planning
- Data analysis methods (quantitative and qualitative data; quantitative analysis of survey data; qualitative analysis - content analysis, discourse analysis, case study, comparative research)
- *Research ethics
- Decisions based on incomplete information
- Dealing with complex systems/roughness
- *Role of science in planning - the perspective of both research and practice

Lecture notes
Learning materials: available online (Moodle) before corresponding lecture.

Literature

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

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

Domain C - Social Competencies

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

Domain D - Personal Competencies

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

101-0491-00L Agent Based Modeling in Transportation

6 credits

W 4G

M. Balac

Abstract
This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.

Objective
At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform practical transportation studies
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based microsimulation, where different statistical methods used in the process will be introduced and explained
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).

The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g., creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:
- Car following models
- Lane change models
- Calibration and validation methodology

Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibration, analyze and presentation) across the semester. A mid-term and final examination of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

The lecture notes and additional handouts will be provided before the lectures. Additional literature recommendations will be provided at the lectures.

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.
This course will provide an introduction to the methods and tools that can be used to determine optimal inspection and intervention strategies and work programs for infrastructure.

Upon successful completion of this course students will be able:
- to use preventive maintenance models, such as block replacement, periodic preventive maintenance with minimal repair, and preventive maintenance based on parameter control, to determine when, where and what should be done to maintain infrastructure
- to take into consideration future uncertainties in appropriate ways when devising and evaluating monitoring and management strategies for physical infrastructure
- to use operation research methods to find optimal solutions to infrastructure management problems

Part 1:
Explanation of the principal models of preventative maintenance, including block replacement, periodic group repair, periodic maintenance with minimal repair and age replacement, and when they can be used to determine optimal intervention strategies

Part 2:
Explanation of preventive maintenance models that are based on parameter control, including Markovian models and opportunistic replacement models

Part 3:
Explanation of the methods that can be used to take into consideration the future uncertainties in the evaluation of monitoring strategies

Part 4:
Explanation of how operations research methods can be used to solve typical infrastructure management problems.

A script will be given out at the beginning of the course.

Class relevant materials will be distributed electronically before the start of class.

A copy of the slides will be handed out at the beginning of each class.

Successful completion of IM1: 101-0579-00 Evaluation tools is a prerequisite for this course.

101-0419-02L 
Railway Infrastructures 2 

Abstract
Track geometry including calculation and measuring as well as related data systems; clearance profiles; interaction between track and vehicles, vehicle dynamics, stress; track construction including special features of railway bridges and tunnels; environmental aspects in track construction; track diagnostics and forecast; track maintenance and related methods

Objective
The lecture gives a deeper insight into track geometry including clearance profile, the interaction between track and vehicles as well as in construction and dimensioning of the track. Methods for the diagnosis of the state of the track and its forecast are shown. State-of-the-art maintenance strategies and technologies are presented.

Content
1 - Track geometry
Track geometry including calculation and measuring as well as related data systems; clearance profiles

2 - Interaction
Interaction between track and vehicles, vehicle dynamics

3 - Railway Track
Stress; track construction including special features of railway bridges and tunnels

4 - Environmental aspects in track construction
Fundamentals; noise protection; vibration protection

5 - Diagnostics, maintenance strategies
Track diagnostics and forecast; maintenance strategies

Literature
A list with related technical literature will be handed out.

Prerequisites / notice
Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)

Major in Hydraulic Engineering and Water Resources Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0249-00L</td>
<td>Hydraulic Engineering: Selected Topics</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>R. Boes</td>
</tr>
<tr>
<td>101-0289-00L</td>
<td>Applied Glaciology</td>
<td>W</td>
<td>4 credits</td>
<td>2G</td>
<td>D. Farinotti, A. Bauder, M. Werder</td>
</tr>
</tbody>
</table>

The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

The objectives of the courses are to:
- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.
Content
The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacial mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

Lecture notes
Digital lecture handouts will be distributed prior to each class.

Literature
Links to relevant literature will be provided during the classes.

Prerequisites / notice
Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

**Domain C - Social Competencies**

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

**Domain D - Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

101-1249-00L Hydraulics of Engineering Structures W 3 credits 2G I. Albayrak, F. Evers

Abstract
Hydraulic fundamentals are applied to hydraulic structures for wastewater, flood protection and hydropower. Typical case studies from engineering practice are further described.

Objective
Understanding and quantification of fundamental hydraulic processes with particular focus on hydraulic structures for wastewater, flood protection and hydropower

Content

1. Introduction & Basic equations
2. Losses in flow & Maximum discharge
3. Uniform flow & Critical flow
4. Hydraulic jump & Stilling basin
5. Backwater curves
6. Weirs & End overfall
7. Sidewir & Side channel
8. Bottom opening, Venturi & Culverts, Restrictors, Inverted siphons
9. Fall manholes & Vortex drop
10. Supercritical flow & Special manholes
11. Aerated flows & Low level outlets
12. Hydraulics of sediment bypass tunnels
13. Vegetated flows - Introduction & Application
14. Summary

Lecture notes
Text books

Literature

Exhaustive references are contained in the suggested text book.

102-0215-00L Urban Water Management II W 4 credits 2G M. Maurer, P. Staufer

Abstract

Objective
Consolidation of the basic procedures for design and operation of technical networks in water engineering.

Content

Demand Side Management versus Supply Side Management
Optimierung von Wasserverteilnetzen
Kalkausfällung, Korrosion von Leitungen
Hygiene in Verteilnetzen
Siedlungshydrologie: Niederschlag, Ablussbildung
Instationäre Strömungen in Kanalisationen
Stofftransport in der Kanalisation
Einleitbedingungen bei Regenwetter
Versickerung von Regenwasser
Generelle Entwässerungsplanung (GEP)

Lecture notes
Written material will be available digital.

Prerequisites / notice
Prerequisite: Introduction to Urban Water Management
Abstract

Objective
To recognise and understand channel and hillslope processes and their interactions. To learn about methods of hazard analysis and of technical and bioengineering protection measures and their assessment. Determination of critical loads and design of protective structures. Assessment of spatial and future developments with and without protective measures.

Content

Lecture notes
see "Literatur"

Literature

Prerequisites / notice
Besonderes
Requirements:
- Essentials of Construction Analysis
- Hydraulics
- Geology and Petrography
- Soil Physics
- Soil Mechanics and Geotechnics

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Technics and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Critical Thinking: not assessed
- Creativity: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Major in Materials and Mechanics

Number Title Type ECTS Hours Lecturers
101-0639-01L Science and Engineering of Glass and Natural Stone in Construction W 3 credits 2G F. Wittel, T. Wangler

Abstract
The course offers an overview of relevant practical issues and present technological challenges for glass and natural stones in constructions. Students gain a good knowledge of the basics of glasses and natural stones, their potential as engineering materials and learn to apply them in the design of civil engineering constructions and to evaluate concepts.
Objective

Glass is increasingly used in constructions to ease the construction process, as functional insulation barrier, even for structural applications of impressive size. While everyone has experienced the innovation potential of glass in the last decade, products from natural stone suffer from an unjustified traditional image that often originates from a lack of understanding of the material and its combination with other materials. Culturally important structures often are made from natural stone and their conservation demands an understanding of their deterioration mechanisms, the concepts of which can be applied to other civil engineering materials. Designers and engineers need the knowledge to reconcile materials and system behavior with the entire processing, handling, integration and life time in mind.

In this module students are provided with a broad fundamental as well as practice-oriented education on glass and natural stone in civil engineering applications. Present and future construction and building concepts demand for such materials with optimized properties. Based on the fundamentals from the Bachelor course in materials by the end of this module, you should be able to:

- recognize and choose specific applications from the broad overview you were provided with;
- relate processing technologies to typical products and building applications and recognize (and explain typical damage related to wrong material choice or application;
- explain the nature of glassy and crystalline materials and interpret their physical behavior against this background;
- explain the major deterioration mechanisms in natural stone and how this relates to durability;
- analyze material combinations and appraise their application in future products as well as integration in existing constructions;
- summarize with appropriate guidance publications on a related topic in an oral presentation and short report.

Content

Lecture 1: An introduction to science and engineering of glass and natural stone in construction (FW/TW)

Lecture 2: Glass chemistry including historical development of glass composition, use of raw materials, melts, chemical stability and corrosion. (FW)

Lecture 3: Geology and mineralogy of stones used in construction. Formation processes, chemistry, crystal structure. (TW)

Lecture 4: Microscopic models for glassy materials. Physics of vitrification. From microscopic physical models to thermodynamics, rheology and mechanics of glassy materials. (FW)

Lecture 5: Stone properties and behavior: microstructure, density, porosity, mechanical properties (TW)

Lecture 6: Glass physics: Optical properties (transmission, reflection, emission, refraction, polarization and birefringence, testing methods); Mechanical properties (density, thermal, mechanical, electric properties, glass testing) (FW)

Lecture 7: Stone properties and durability: transport, moisture and thermal cycling (TW)

Lecture 8: Forming and processing of glass: (plate and molded glass, drawing, slumping, profiling etc.; Processing: Cutting, mechanical processing, tempering, gluing, bending, laminating of glass Surface treatments: coating, sputtering, enameling, printing, etching, chemical pre-stressing.) (FW)

Lecture 9: Durability: Salt crystallization, freezing, biodeterioration (TW)

Lecture 10: Glass products for civil engineering applications: (Molded glasses, fiber glass, foam glass, plate glass); construction glass (insulation glass, structural glass, protective glass, intelligent glass, codes); (FW)

Lecture 11: Conservation: Consolidation, cleaning, and other treatments (TW).

Lecture 12: Glass in constructions. (modelling, application and regulation, typical damage in glass) (FW)

Lecture 13: Student presentations; exam questions (FW/TW)

Lab 1: Durability of natural stone (FW/TW)

Lab 2: Fracture of glass (FW/TW)

Will be handed out in the lectures

Werkstoffe II script (download via the IFB homepage). Rest will be handed out in the lectures

Werkstoffe I/II of the bachelor studies or equivalent introductory materials lecture.

Domain A - Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain B - Method-specific Competencies

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

Domain C - Social Competencies

- Communication assessed
- Self-presentation and Social Influence assessed

Domain D - Personal Competencies

- Creative Thinking assessed
- Critical Thinking assessed
- Self-direction and Self-management assessed

101-0659-01L Durability and Maintenance of Reinforced Concrete W 4 credits 2V U. Angst, Z. Zhang

Abstract

We look at the durability of reinforced concrete structures, covering common deterioration processes such as reinforcement corrosion, frost damage, ASR, etc. The course spans the range from fundamental mechanisms to aspects of engineering practice. New methods and materials for preventative measures, condition assessment and repair techniques are treated. Examples from real cases are shown.
After this course you will have profound understanding about:

- the different mechanisms of deterioration of concrete structures, in particular reinforcement corrosion
- the relevant parameters affecting durability of reinforced concrete (cover depth, concrete quality, moisture, etc.)

Furthermore, you will know:

- current engineering approaches for durability design (according to standards) and their limitations
- refined models for enhanced durability design and service life predictions
- preventive measures to improve durability (e.g. stainless steel reinforcement, concrete surface coatings, etc.)
- the particular durability challenges with post-tensioned structures and ways to overcome them (electrically isolated tendons)
- methods for inspection and condition assessment of existing, ageing structures (including non-destructive techniques and monitoring with sensors)
- repair methods for deteriorated concrete structures such as conventional repair and electrochemical methods (in particular cathodic protection)
- possible future problems for durability that may arise with modern materials and construction technologies

Possible future problems for durability that may arise with modern materials and construction technologies

- Socio-economic challenges related to ageing infrastructures
- Degradation mechanisms for concrete: sulphate attack, ASR, frost attack.
- Inspection and condition assessment: Chloride analyses, carbonation depth, etc. Non-destructive tests, particularly potential mapping to detect corrosion. New developments (for example, monitoring with sensors).
- Stainless steel as reinforcing steel for concrete: Different types of stainless steels. Coupling with black reinforcing steel. Examples of application. Life-cycle-costs.
- Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.

Excursion:

- We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

Lecture notes

The course is based on the book


Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed

Literature

The course is based on the book


Slides of the lectures will be distributed in advance

Prerequisites / notice

The course is a lecture that contains frequent discussion and interaction between students and lecturer. You will see and work on many examples from engineering practice, both during the lectures and in the form of exercises to be solved at home.

Report:

Each student will work on a small case study and deliver a report during the semester. The report will be graded.

Excursion:

We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

**Domain A - Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**

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

**Domain C - Social Competencies**

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

**Domain D - Personal Competencies**

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

101-0689-00L Shrinkage and Cracking of Concrete: Mechanisms and Impact on Durability

W 3 credits 2V P. Lura, M. Wyrzykowski

Concrete is generally viewed as a durable construction material. However, the long-term performance of a concrete structure can be greatly compromised by early-age cracking. This course will explain how shrinkage of concrete leads to cracking and how control of shrinkage allows increasing the expected durability of a concrete structure.
This course begins with a brief introduction about hydration and microstructure development in cement paste and concrete. The students will learn the main causes of cracking at early ages, namely plastic, drying, thermal, and autogenous shrinkage, with special emphasis on the driving mechanisms. The importance of concrete curing, especially in the first few days after casting, will be stressed and explained. Building on the knowledge of the driving forces of shrinkage, the way of action of shrinkage-reducing admixtures will be clarified and different applications illustrated. As an extension of external curing, the students will become familiar with internal curing by means of saturated lightweight aggregates and superabsorbent polymers.

Most concrete members are restrained by adjacent structures. When shrinkage is restrained, cracks may develop. The students will learn how to apply different criteria for assessing concrete cracking and how to retrieve the mechanical properties of the concrete, especially stiffness and creep, which are needed for the calculations of self-induced stresses and risk of cracking.

In addition to macroscopic cracks, microcracking may occur in the cement paste due to inner restraint offered by the aggregates. Both macroscopic cracks and diffuse microcracking within a concrete may facilitate the ingress of harmful substances (e.g., chloride and sulfate ions) into the concrete; these may react with the concrete or with the reinforcement and create further deterioration. The students will acquire an understanding of the mechanisms of transport through cracked concrete, with special focus on experimental evidence and on techniques able to visualize the transport process and follow it in time.

As a final outcome of the course, the students will be able to estimate the impact of cracking on the expected durability of concrete structures and to implement different types of measures to reduce the extent of cracking.

Concrete is generally viewed as a long-lasting construction material. However, the durability of a concrete structure can be jeopardized by shrinkage-induced cracking. In addition to being unsightly, cracks have the potential to act as weak planes for further distress or as conduits for accelerated ingress of aggressive agents that may reduce durability.

Advances in concrete technology over the past decades have led to the practical use of concrete with a low water to binder ratio and with different types of mineral and organic admixtures. Another recent development is self-compacting concrete, which avoids concrete vibration and reduces labor during placing. Unfortunately, these concretes are especially prone to cracking at early ages, unless special precautions are taken. Proper curing becomes in this case the key to achieve better performance in various environmental and load conditions.

Specific topics covered by the course:
- Hydration
- Microstructure development
- Plastic shrinkage
- Development of mechanical properties
- Thermal deformation
- Autogenous deformation
- Drying shrinkage
- Creep and relaxation
- Curing
- Shrinkage-reducing admixtures
- Internal curing: saturated lightweight aggregates and superabsorbent polymers
- Fracture and microcracking
- Transport in cracked concrete
- Impact of cracking on concrete durability
- Self-healing of cracks

Lecture notes
For each lecture, lecture notes will be provided. In addition, one or two research papers for each lecture will be indicated as supportive information.

Literature
Copies of one to two research papers relevant to the topic of each lecture will be provided to the students as supportive information.

101-0657-10L Wood Structure and Function

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Learning target is a basic understanding of the anatomy of wood and the related impact of endogenous and exogenous factors. The students can learn how to distinguish common central European wood species at the macroscopic and microscopic level. A deeper insight will be given by wood identification exercises for softwood species. Further, the students will gain insight into the relationships between tree growth and wood properties with a specific focus on the wood function in the living tree.</td>
<td>In an introduction to wood anatomy, the general structural features of softwoods and hardwoods will be explained and factors of diversity and variability will be discussed. A specific focus is laid on common central European tree species with relevance in the wood sector, which will be studied in macro- and microstructural investigations. In the following, relationships between wood structure, properties and function in the living tree will be in the focus of the lectures. Topics covered are water transport, trends in wood anatomy within trees, environmental impact on wood anatomy, wood defects and their causes, tools to study wood properties over time, secondary changes in wood, and tree biomechanics.</td>
<td><em>This course offers no introduction to commercial software.</em></td>
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</table>

101-0657-20L Fundamentals of Wood Elaboration and Woodmachining

<table>
<thead>
<tr>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning target is a fundamental understanding of the dominating wood machining processes, which are applied to fabricate common wood products. Students will be introduced to the economic relevance of the renewable resource wood and are trained in its technological properties. The students will learn to identify the relationships between wood species and their properties as well as the suitable wood machining processes to fabricate targeted wood products. Finally, the digital transformation process, which will affect all sectors of the wood industry with impact on the entire value chain and business models will be covered. It will be illustrated how production processes will become more flexible, efficient and less resource demanding.</td>
<td>The general introduction shows the economic relevance of the resource wood in a global, European and Swiss context and reflects aspects of sustainability in wood production and certification. In terms of bulk wood products a specific focus is laid on sawn timber production and drying processes. With regard to wood veneer production, steaming, veneer cutting and assembly to veneer lumber products are presented. Further the common technologies for the production of particle boards and fibre boards as well as paper will be discussed. In the following, the topics are related to wood gluing and wood protection as well as potentials and limitations in the application of wood and wood-based products. In a further part, the lecture deals with the most important digital technologies, e.g., Internet of Things, artificial intelligence and their impact on the wood industry on the basis of illustrative examples. At the end of the lecture an excursion to a Swiss wood manufacturer is planned, in order to facilitate practical experience.</td>
<td>Copies of one to two research papers relevant to the topic of each lecture will be provided to the students as supportive information.</td>
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</table>

101-0159-00L Method of Finite Elements II

<table>
<thead>
<tr>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Method of Finite Elements II is a continuation of Method of Finite Elements I. Here, we explore the theoretical and numerical implementation concepts for the finite element analysis beyond the linear elastic behavior. This course aims to offer students with the skills to perform nonlinear FEM simulations using coding in Python. <em>This course offers no introduction to commercial software.</em></td>
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</tbody>
</table>

Objective

This class overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity. In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

The course specifically covers the treatment of the following phenomena:
- Material Nonlinearity (Plasticity)
- Geometric Nonlinearity (Large Displacement Problems)
- Nonlinear Dynamics
- Fracture Mechanics

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

See the class webpage for more information:

Lecture notes

The course slides serve as Script. These are openly available on: http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Useful (optional) Reading:

Prerequisites / notice

Prerequisites:
-101-0158-01  Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories

Domain B - Method-specific Competencies
Analytical Competencies

Domain C - Social Competencies
Cooperation and Teamwork

Domain D - Personal Competencies
Critical Thinking

Upon completion of the course, the participants will be able to:
- Fracture Mechanics
- Nonlinear Dynamics
- Geometric Nonlinearity (Large Displacement Problems)
- Material Nonlinearity (Plasticity)

The course specifically covers the treatment of the following phenomena:
- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

Projects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0198-10L</td>
<td>Project on Construction Engineering</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
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<tr>
<td>Abstract</td>
<td>Working on a concrete task in Construction Engineering</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.</td>
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</tr>
<tr>
<td>Content</td>
<td>The project work is supervised by a professor. Students can choose from different subjects and tasks.</td>
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<tr>
<td>101-0298-10L</td>
<td>Project on Hydraulic Engineering and Water Resources Management</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
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<tr>
<td>101-0398-10L</td>
<td>Project on Geotechnical Engineering</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
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<td>Abstract</td>
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<tr>
<td>101-0498-10L</td>
<td>Project on Transport Systems</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
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<tr>
<td>Abstract</td>
<td>Working on a concrete task on Transport Systems</td>
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<tr>
<td>101-0598-10L</td>
<td>Project on Construction and Maintenance Management</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
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<td>Abstract</td>
<td>Working on a concrete task in Construction and Maintenance Management</td>
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<tr>
<td>101-0698-10L</td>
<td>Project on Materials and Mechanics</td>
<td>W</td>
<td>11 credits</td>
<td>24A</td>
<td>Supervisors</td>
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<tr>
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</table>
This course is an introduction to innovative construction project delivery through three strategies: integrated information, integrated organization, and integrated processes. Students will be introduced to project and production management concepts such as Lean Construction, Building Information Modeling, the Tri-Constraint Method, & Integrated Project Delivery.

By the end of the course, students will be able to plan and manage the lean, integrated, and digital project delivery of a construction project.

Students will know they are able to achieve this overall course goal when they can:

1. Understand the fundamentals of Virtual Design and Construction and Building Information Modeling. This includes the ability to prepare a model breakdown structure capable of integrating project information for all stakeholders; describe the upcoming transition to a common data environment for BIM that will use platforms such as Autodesk Forge; and describe the barriers to successful implementation of BIM within construction and design firms.

2. Evaluate benefits of integrated project governance compared to the organization of traditional construction project delivery systems. This includes the ability to evaluate the risks, benefits and considerations for integrated teams using multi-party relational contracts that cross disciplinary and firm boundaries; and explain to others the 'elements' of integrated projects (e.g. colocation, early involvement of key stakeholders, shared risk/reward, collaborative decision making).

3. Plan and schedule an integrated ‘SD’ scope schedule cost model using the Tri-Constraint Method. This includes the ability to understand the TCM algorithm, apply parametric logic to the creation of a virtual model for construction production; and evaluate the limitations of the critical path method when compared to resource- and space-constrained scheduling.

4. Understand the benefits of collaborative decision making. This includes the ability to describe the criteria of four focus areas – buildability, operability, usability, and sustainability. The project must be buildable, as measured by metrics of cost, schedule, and quality. It must be operable, as measured by the cost of maintaining the facility for the duration of its lifecycle. It must be usable, enabling productivity, efficiency and well-being of those who will inhabit the building. Finally, it must be sustainable, minimizing the use of resources such as energy and water. Buildings that succeed in all four of these areas can be considered HP projects.

For integrated processes, students will be introduced to the fundamentals of lean construction management. This course will look at the causes of variability in construction production and teach the theory of lean production to several construction management tools including the Last Planner System, Pull Planning, Target Value Design, and Takt Planning.

1. Students will have the opportunity to discuss barriers in the industry to more advanced implementation of BIM and VDC.

2. For integrated organization, students will study the limitations of the construction industry to effectively organize for complex projects, including the challenges of managing highly interdependent tasks and generating knowledge and learning within large multi-organizational project teams. One emerging approach in North America known as IPD will be studied as a case example. Students will explore the benefits of certain ‘elements’ of IPD such as project team colocation, early involvement of trade contractors, shared risk/reward contracts, and collaborative decision making.

3. The construction industry is continually seeking to deliver High-Performance (HP) projects for their clients. HP buildings must meet the requirements of four focus areas – buildability, operability, usability, and sustainability. The project must be buildable, as measured by metrics of cost, schedule, and quality. It must be operable, as measured by the cost of maintaining the facility for the duration of its lifecycle. It must be usable, enabling productivity, efficiency and well-being of those who will inhabit the building. Finally, it must be sustainable, minimizing the use of resources such as energy and water. Buildings that succeed in all four of these areas can be considered HP projects.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
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</thead>
<tbody>
<tr>
<td>101-0317-00L</td>
<td>Tunnelling I</td>
<td>W 3 credits 2G</td>
<td>G. Anagnostou, E. Pimentel</td>
<td></td>
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<tr>
<td>101-0187-00L</td>
<td>Structural Reliability and Risk Analysis</td>
<td>W 3 credits 2G</td>
<td>S. Marelli</td>
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<tr>
<td>101-0437-00L</td>
<td>Traffic Engineering</td>
<td>W 6 credits 4G</td>
<td>A. Kouvelas</td>
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<tr>
<td>101-0417-00L</td>
<td>Transport Planning Methods</td>
<td>W 6 credits 4G</td>
<td>K. W. Axhausen</td>
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</tr>
</tbody>
</table>

**Objective**:

- **Tunnelling I**: Basic aspects of design and analysis of underground structures. Conventional tunnel construction methods. Auxiliary measures (ground improvement and drainage, forepoling, face reinforcement). Numerical analysis methods.
- **Structural Reliability and Risk Analysis**: Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.
- **Traffic Engineering**: Fundamentals of traffic flow theory and control.
- **Transport Planning Methods**: The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

**Content**:

- **Tunnelling I**: Conventional excavation methods (full face, top heading and bench, side drift method, ...)
- **Structural Reliability and Risk Analysis**: The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. The framework of risk analysis allows one to incorporate the uncertainty in decision making.
- **Traffic Engineering**: Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.
- **Transport Planning Methods**: The ecosystem of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

**Prerequisites / notice**:

- **Traffic Engineering**: Basic course on probability theory and statistics.
- **Transport Planning Methods**: Special permission from the instructor can be requested if the student has not taken Verkehr III - Road Transport Systems 6th Sem. BSc (101-0415-00L)

**Lecture notes / Literature**:

- **Tunnelling I**: Empfehlungen, Domain A - Subject-specific Competencies, Domain B - Method-specific Competencies.
- **Structural Reliability and Risk Analysis**: Lecture notes, Lecture notes and additional handouts will be provided during the lectures.
- **Traffic Engineering**: Slides of the lectures are available online every week. Additional literature recommendations will be provided during the lectures.
- **Transport Planning Methods**: Additional handouts will be provided during the lectures.
Content

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes

Moodle platform (enrollment needed)

Literature


101-0491-00L

Agent Based Modeling in Transportation

W 6 credits 4G M. Balac

Abstract

This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.

Objective

At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform practical transportation studies

Content

This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:
1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained. Here the open-source egasim framework used at ETH Zurich to set up agent-based models will be introduced
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

Literature

Agent-based modeling in general
MATSim

Prerequisites / notice

Additional relevant readings, primarily scientific articles, will be recommended throughout the course.

There are no strict preconditions in terms of which lectures the students should have previously attended. However, knowledge of basic statistical theory is expected, and experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

101-0507-00L

Infrastructure Management 3: Optimisation Tools

W 6 credits 2G B. T. Adey

Abstract

Does not take place this semester.

Objective

Upon successful completion of this course students will be able:
- to use preventive maintenance models, such as block replacement, periodic preventive maintenance with minimal repair, and preventive maintenance based on parameter control, to determine when, where and what should be done to maintain infrastructure
- to take into consideration future uncertainties in appropriate ways when devising and evaluating monitoring and management strategies for physical infrastructure
- to use operation research methods to find optimal solutions to infrastructure management problems

Content

Part 1:
Explanation of the principal models of preventative maintenance, including block replacement, periodic group repair, periodic maintenance with minimal repair and age replacement, and when they can be used to determine optimal intervention strategies

Part 2:
Explanation of preventive maintenance models that are based on parameter control, including Markovian models and opportunistic replacement models

Part 3:
Explanation of the methods that can be used to take into consideration the future uncertainties in the evaluation of monitoring strategies

Part 4:
Explanation of how operations research methods can be used to solve typical infrastructure management problems.

Lecture notes

A script will be given out at the beginning of the course.
Class relevant materials will be distributed electronically before the start of class.
A copy of the slides will be handed out at the beginning of each class.

Prerequisites / notice

Successful completion of IM1: 101-0579-00 Evaluation tools is a prerequisite for this course.
Numerical Hydraulics

Objective

The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

Content

The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available software such as BASEMENT for non-steady shallow water flows are used.

Lecture notes

Lecture notes, powerpoints shown in the lecture and programs used can be downloaded. They are also available in German.

Literature

Given in lecture

Method of Finite Elements II

Abstract

The Method of Finite Elements II is a continuation of Method of Finite Elements I. Here, we explore the theoretical and numerical implementation concepts for the finite element analysis beyond the linear elastic behavior. This course aims to offer students with the skills to perform nonlinear FEM simulations using coding in Python.

"This course offers no introduction to commercial software.

Objective

This course overviews advanced topics of the Method of Finite Elements, beyond linear elasticity. Such phenomena are particularly linked to excessive loading effects and energy dissipation mechanisms. Their understanding is necessary for reliably computing structural capacity.

In this course, instead of blindly using generic structural analysis software, we offer an explicit understanding of what goes on behind the curtains, by explaining the algorithms that are used in such software.

The course specifically covers the following phenomena:

- Material Nonlinearity (Plasticity)
- Geometric Nonlinearity (Large Displacement Problems)
- Nonlinear Dynamics
- Fracture Mechanics

The concepts are introduced via theory, numerical examples, demonstrators and computer labs in Python (starting Fall 2021).

Upon completion of the course, the participants will be able to:

- Recognize when linear elastic analysis is insufficient
- Solve nonlinear dynamics problems, which form the core for limit state calculations (e.g. ultimate capacity, failure) of structures
- Numerically simulate fracture; a dominant failure phenomenon for structural systems.

See the class webpage for more information:


Lecture notes

The course slides serve as Script. These are openly available on: http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Course Slides (Script): http://www.chatzi.ibk.ethz.ch/education/method-of-finite-elements-ii.html

Useful (optional) Reading:


Prerequisites / notice

Prerequisites:

-101-0158-01  Method of Finite Elements I (FS)
- A good knowledge of Python is necessary for attending this course.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain C - Social Competencies
- Cooperation and Teamwork

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking

Computational Science Investigation for Material Mechanics

Abstract

Introduction to computational sciences with focus on numerical modeling of the mechanics of materials. Simulation of material damage and failure with advanced finite element methods.

Objective

Learning from mistakes and failures is as old as the engineering discipline. Understanding why things went wrong is essential for improvement, but often impossible without the help of numerical modelling. Real world problems are often highly nonlinear, dependent on multiple physical fields, involve fundamental material behavior far from equilibrium and reversibility, and can often only be understood by addressing different relevant scales.

In this course, we will use real-life cases to learn how to deal with such problems. Starting from the problem description with governing equations, you will learn how to tackle non-linear and multi-field problems using numerical simulations. A particular focus will be on fracture. Starting from the failed state, we will investigate potential causes and find the conditions that resulted in failure. For doing so, you will learn how to predict it with the Finite Element Method (FEM). To correctly assess failure, plastic behavior and size effects, originating from the underlying material microstructure, need to be considered. You will learn how to deal with plasticity in FEM and how you can get information from the heterogeneous material scale into your FEM framework.

Content

1 Introduction to (numeric) forensic engineering
2 The nature of engineering problems (governing equations)
3 Numerical recipes for dealing with non-linear problems
4 Multi-field problems (HTM; Comsol)
5 On the nature of failure - Physics of damage and fracture
6 Cracks and growth in structures (LEFM and beyond)
7 A practical approach to LEFM with FEM (Abaqus)
8 Introduction to metal plasticity
9 Damage and fracture in heterogeneous materials
10 Mechanics of fatigue
11 Visco-elastic failure
12 Student -Project presentation

Lecture notes

Will be provided during the lecture via moodle.

Literature

Will be provided during the lecture.
101-0185-01L
CAD for Civil Engineers

Abstract
Introduction to computer aided design and drafting in 2D and 3D with examples from structural engineering

Objective
Point in time of enrolment of course is decisive.

Having followed the course, students are able to develop a 2D-structure (formwork drawing) and they know the principle of a reinforcement module. They have also got an introduction to a 3D program (reinforcement in 3D).

Above all they practice spatial sense and acquire contextual knowledge as future superiors of draftsmen and designers.

Prerequisites / notice
Familiarity with MATLAB and / or Python is advised.

101-0250-00L
Solving Partial Differential Equations in parallel on GPUs

Abstract
This course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

Objective
When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

Content
Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

Part 2 - Developing your own parallel algorithms
- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

Part 3 - Final project
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes
Digital lecture notes, interactive Julia notebooks, online material.

Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

101-0139-00L
Scientific Machine and Deep Learning for Design and Construction in Civil Engineering

Abstract
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction in civil engineering. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

Objective
This course aims to provide graduate level introduction into Machine and especially scientific Machine Learning for applications in the design and construction phases of projects from civil engineering.

Content
The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

Lecture notes
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

Literature
Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning
O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

Prerequisites / notice
Familiarity with MATLAB and / or Python is advised.

101-0120-00L
Structural Glass Design and Facade Engineering

Abstract
Number of participants is limited to 30.

Objective
- Assess a problem and apply ML and DL in a computational framework accordingly
- Incorporating scientific domain knowledge in the SciML process
- Define, Plan, Conduct and Present a SciML project
- Understand main ML background theory and methods
- Apply your new skills in a final project;
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Literature
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Part 3 - Final project
- Apply your new skills in a final project;
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Lecture notes
Digital lecture notes, interactive Julia notebooks, online material.

Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.
There are a large number of efforts around the world to obtain more net benefits from infrastructure assets. This can be seen through the proliferation of codes and guidelines and the increasing amount of research in road infrastructure asset management. Many of these codes and guidelines exist independently of each other. This can be attributed to the complexity and diversity of the problem and the need for flexibility. It is, however, important to note that these codes and guidelines are often developed in isolation and without consultation with each other. This can lead to conflicting recommendations and a lack of consistency in the implementation of these codes and guidelines.

The course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students with the knowledge required to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.

**Lectures:**

The lectures will cover the following contents:

- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);
- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);
- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);
- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);
- Typologies and design of structural systems for transparent façades;
- Requirements and functions for transparent façades.

**Design exercises:**

The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specific details of numerical calculation procedures are exemplified with the software Abaqus.

**Design project:**

The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.

**Literature**

Recommended and supplementary literature:


**Prerequisites / notice**

Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.
Content

The weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management, with emphasis on the consideration of the benefits and costs of infrastructure to all members of society, and balancing the need for prediction accuracy with analysis effort. The expectations of your throughout the semester, including a description of the project.

2. Positioning infrastructure management in society. As infrastructure plays such an integral part in society, there is considerable need to ensure that infrastructure managers are managing it as best possible. A prominent network regulator explains the role and activities of a network regulator.

3. Setting goals and constraints – To manage infrastructure you need to know what you expect from it in terms of service and how much you are willing to pay for it. We discuss the measures of service for this purpose, as well as the ideas of quantifiable and non-quantifiable benefits, proxies of service, and valuing service.

4. Predicting the future – As infrastructure and our expectations of service from it change over time, these changes need to be included in the justification of management activities. This we discuss the connection between provided service and the physical state of the infrastructure and one way to predict their evolution over time.

5. Help session 1

6. Determining and justifying general interventions - It is advantageous to be able to explain why infrastructure assets need to be maintained, and not simply say that they need to be maintained. This requires explanation of the types of interventions that should be executed and how these interventions will achieve the goals. It also requires explaining which interventions are to be done if it is not possible to do everything due to for example budget constraints. This week we cover how to determine optimal intervention strategies for individual assets, and how to convert these strategies into network level intervention programs.

7. Determining and justifying monitoring - Once it is clear how infrastructure might change over time, and the optimal intervention strategies are determined, you need to explain how you are going to know that these states exist. This requires the construction of monitoring strategies for each of asset. This week we focus on how to develop monitoring strategies that ensure interventions are triggered at the right time.

8. Converting programs to projects / Analysing projects – Once programs are completed and approved, infrastructure managers must create, supervise and analyse projects. This week we focus on this conversion and the supervision and analysis of projects.

9. Help session 2

10. Ensuring good information – Infrastructure management requires consistent and correct information. This is enabled by the development of a good information model. This week we provide an introduction to information models and how they are used in infrastructure management.

11. Ensuring a well-run organization – How people work together affects how well the infrastructure is managed. This week we focus on the development of the human side of the infrastructure management organisation.

12. Describing the IM process – Infrastructure management is a process that is followed continually and improved over time. It should be written down clearly. This week we will concentrate on how this can be done using the formal modelling notation BPMN 2.0.

13. Evaluating the IM process – Infrastructure management processes can always be improved. Good managers acknowledge this, but also have a plan for continual improvement. This week we concentrate on how you can systematically evaluate the infrastructure management process.

14. Help session 3 and submission of project report.

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R.

Lecture notes

- The lecture materials consist of handouts, the slides, and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

Literature

- This course has no prerequisites.

Prerequisites / notice

- Appropriate literature will be handed out when required via Moodle.

Taught competencies

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

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

- Domain C - Social Competencies
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed

- Domain D - Personal Competencies
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: not assessed
  - Critical Thinking: not assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed

101-0492-00L

Microscopic Modelling and Simulation of Traffic Operations

W 3 credits 2G M. Makridis

Abstract

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

Objective
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication. Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

Content
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:
- Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
- Calibrating and validating the simulation model.
- Redesigning/extending the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and present) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Lecture notes / literature
The lecture notes and additional handbooks will be provided before the lectures. Additional literature recommendations will be provided at the lectures.

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

101-0123-00L Structural Design

Abstract
The goal of the course is to introduce the civil engineering students to Structural Design, which is regarded as a discipline that relates structural behavior, construction technologies and architectural concepts. The course encourages the students to understand the relationship between the form and the forces within it by promoting the development of designed projects.

Objective
After successfully completing this course the students will be able to:
1. Critically question structural design concepts of historical and contemporary references
2. Use graphic statics and strut-and-tie models based on the theory of Plasticity to describe the load bearing behavior of structures
3. Understand different construction technologies and have an awareness of their potential for structural design
4. Use contemporary digital tools for the design of structures in equilibrium
5. Design an appropriate structural system for a given design task taking into account architectural considerations

Content
The goal of the course is to introduce the civil engineering students to Structural Design, which is understood as a discipline that relates structural behavior, construction technologies and architectural concepts. Hence, the course encourages the students to develop an intuitive understanding of the relationship between the form of a structure and the forces within it by promoting the development of designed projects, in which the static and architectural aspects come together. The course is structured in two main parts, each developed in half of a semester: a mainly theoretical one (including the teaching of graphic statics) and a mainly applied one (focused on the development of a design project by the students using digital form-finding tools).

Theory
Graphic statics is a graphical method developed by Prof. Karl Culmann and firstly published in 1864 at ETH Zurich. In this approach to structural analysis and design, geometric construction techniques are used to visualize the relation between the geometry of a structure and the forces acting in and on it, represented by geometrically dependent form and force diagrams.

The course will firstly review the main principles of graphic statics through a series of frontal lectures and discuss the relationship to analytical statics. Graphic statics is then used as an operative tool to design structures in equilibrium based on the lower bound theorem of the Theory of Plasticity. Additionally, the course will introduce contemporary methodologies and tools (parametric CAD software) for the interactive application of equilibrium modelling in the form of short workshops. The students will familiarize with the topic by solving exercises and confronting themselves with simple design tasks.

Design Project
Specific structural design approaches and design methodologies based on graphic statics and references from construction history will be introduced to the students by means of seminars and workshops. By developing a design project, the students will apply these concepts and techniques in order to become proficient with open design tasks (such as the design of a bridge, a large span hall or a tower). At the end of the semester, the students present their projects to a jury of internal and external critics in a final review. The main criterion of evaluation is the students' ability to integrate architectural considerations into their structural design.

Literature
“Faustformel Tragwerksentwurf"
(Philippe Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2015, ISBN 978-3-421-04012-1)

"Form and Forces: Designing Efficient, Expressive Structures"

"The art of structures. Introduction to the functioning of structures in architecture"

102-0468-10L Watershed Modelling

Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).
Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a seminar-end oral examination (30 mins) on watershed modelling concepts.

Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple-bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

101-0121-00L
Fatigue and Fracture in Materials and Structures

Abstract
The fundamentals in fatigue and fracture mechanics, which are used in different engineering disciplines (e.g., for mechanical, aerospace, civil and material engineers) will be discussed. The focus will be on fundamental theories (based on fracture mechanics) that model fatigue damage and crack propagation.

Objective
In this course, the students will learn:

- Linear elastic and elastic-plastic fracture mechanics.
- Modern computer-based techniques (using ABAQUS Finite Element Package) to simulate cracks in both bulk materials and bonded joints/interfaces.
- Laboratory fatigue and fracture tests on details with cracks.

Content
The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered in this course are:

I) Fatigue of materials:
- Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
- Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner's damage rule.
- Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

II) Fracture mechanics:
- Linear elastic fracture mechanics (LEFM): limits of LEFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
- Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
- Fatigue crack growth (FCG): FCG models, Paris’ law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

III) Introduction to cohesive zone models (CZMs):
- Advantages and disadvantages of CZMs compared to fracture mechanics.
- Different bond-slip models for the bonded joints/interfaces.

IV) Computer laboratory to simulate cracks and debonding problems:
- Finite Element (FE) modeling of complex details with cracks.
- FE simulations of debonding problems using CZMs.
- Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

V) Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

VI) Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and “Laboratory Competition”. The students will:
- Visit different small-scale and large-scale fatigue testing equipment.
- Get to know different ongoing fatigue- and fracture-related projects.
- Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
- Compare the experimental results with their own calculations (from the fracture theories).
- Laboratory Competition “Laboratory Competition” at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded by a prize.

Lecture notes
Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.

Literature

Prerequisites / notice
Note 1: A basic knowledge on mechanics of structures and structural analysis (i.e., stress-strain analysis and calculations of internal deformations, strains and stresses within structures) is recommended and will be helpful in the course.

Note 2: Laboratory demonstrations and fatigue/fracture tests at the Structural Engineering Research Laboratory of Empa in Dübendorf. This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

Project Based Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0509-00L</td>
<td>Infrastructure Management 1: Process</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>B. T. Adey</td>
</tr>
</tbody>
</table>

Infrastructure asset management is the process used to ensure that infrastructure provides adequate levels of service for specified periods of time. This course provides an overview of the process, from setting goals to developing intervention programs to analyzing the process itself. It consists of weekly lectures and a group project. Additionally, there is a weekly help session.
Objective

There are a large number of efforts around the world to obtain more net benefits from infrastructure assets. This can be seen through the proliferation of codes and guidelines and the increasing amount of research in road infrastructure asset management. Many of these codes and guidelines and much of the research, however, are focused on only part of the large complex problem of infrastructure asset management.

The objective of this course is to provide an overview of the entire infrastructure management process. The high-level process described can be used as a starting point to ensure that infrastructure management is done professionally, efficiently and effectively. It also enables a clear understanding of where computer systems can be used to help automate parts of the process. Students can use this process to help improve the specific infrastructure management processes in the organisations in which they work in the future.

More specifically upon completion of the course, students will
- understand the main tasks of an infrastructure manager and the complexity of these tasks,
- understand the importance of setting goals and constraints in the management of infrastructure,
- be able to predict the deterioration of individual assets using discrete states that are often associated with visual inspections,
- be able to develop and evaluate simple management strategies for individual infrastructure assets,
- be able to develop and evaluate intervention programs that are aligned with their strategies,
- understand the principles of guiding projects and evaluating the success of projects,
- be able to formally model infrastructure management processes, and
- understand the importance of evaluating the infrastructure management process and have a general idea of how to do so.

Content

The weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management, with emphasis on the consideration of the benefits and costs of infrastructure to all members of society, and balancing the need for prediction accuracy with analysis effort. The expectations of your throughout the semester, including a description of the project.

2. Positioning infrastructure management in society: As infrastructure plays such an integral part in society, there is considerable need to ensure that infrastructure managers are managing it as best possible. A prominent network regulator explains the role and activities of a network regulator.

3. Setting goals and constraints – To manage infrastructure you need to know what you expect from it in terms of service and how much you are willing to pay for it. We discuss the measures of service for this purpose, as well as the ideas of quantifiable and non-quantifiable benefits, proxies of service, and valuing service.

4. Predicting the future – As infrastructure and our expectations of service from it change over time, these changes need to be included in the justification of management activities. This we discuss the connection between provided service and the physical state of the infrastructure and one way to predict their evolution over time.

5. Help session 1

6. Determining and justifying general interventions - It is advantageous to be able to explain why infrastructure assets need to be maintained, and not simply say that they need to be maintained. This requires explanation of the types of interventions that should be executed and how these interventions will achieve the goals. It also requires explaining which interventions are to be done if it is not possible to do everything due to for example budget constraints. This week we cover how to determine optimal intervention strategies for individual assets, and how to convert these strategies into network level intervention programs.

7. Determining and justifying monitoring - Once it is clear how infrastructure might change over time, and the optimal intervention strategies are determined, you need to explain how you are going to know that these states exist. This requires the construction of monitoring strategies for each of asset. This week we focus on how to develop monitoring strategies that ensure interventions are triggered at the right time.

8. Converting programs to projects / Analysing projects – Once programs are completed and approved, infrastructure managers must create, supervise and analyse projects. This week we focus on this conversion and the supervision and analysis of projects.

9. Help session 2

10. Ensuring good information – Infrastructure management requires consistent and correct information. This is enabled by the development of a good information model. This week we provide an introduction to information models and how they are used in infrastructure management.

11. Ensuring a well-run organization – How people work together affects how well the infrastructure is managed. This week we focus on the development of the human side of the infrastructure management organisation.

12. Describing the IM process – Infrastructure management is a process that is followed continually and improved over time. It should be written down clearly. This week we will concentrate on how this can be done using the formal modelling notation BPMN 2.0.

13. Evaluating the IM process – Infrastructure management processes can always be improved. Good managers acknowledge this, but also have a plan for continual improvement. This week we concentrate on how you can systematically evaluate the infrastructure management process.

14. Help session 3 and submission of project report.

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R.

Lecture notes
- The lecture materials consist of handouts, the slides, and example calculations in Excel.

Literature
- The lecture materials will be distributed via Moodle two days before each lecture.

Prerequisites / notice
- Appropriate literature will be handed out when required via Moodle.
- This course has no prerequisites.
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The overarching goal of the course is to deepen knowledge on special aspects in hydraulic engineering and to understand the procedures and the planning sequence of hydropower projects.

The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:
1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation
4. Work as a team to assess and improve the environmental performance of a building project
5. Be able to assess the environmental performance of a building project
6. Be able to assess the environmental performance of a building project

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Part II: Project-based learning
In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

The course will be structured into two parts, each making up about half of the semester.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly the departments ARCH, BAUG, ITET, MAVT, MTEC and UWIS.

No lecture will be given during Seminar week.

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**101-0249-00L**  
**Hydraulic Engineering: Selected Topics**  
W  3 credits  2S  R. Boes  
Prerequisites: 101-0247-01L Hydraulic Engineering II or equivalent course.  

**Abstract**  
The lecture focuses on selected topics in hydraulic engineering, water management and aquatic ecology relating to hydropower and flood protection projects.

**Objective**  
The overarching goal of the course is to deepen knowledge on special aspects in hydraulic engineering and to understand the procedures and the planning sequence of hydropower projects.

**Content**  
Different selected topics in hydraulic engineering will be focused on, e.g. dam safety, materials in dam building, possible problems at reservoirs like natural hazards by impulse waves, the hydraulics of spillways and intake structures at dams and weirs and the area of conflict between hydropower and ecology. Another focus will be put on typical approaches and procedures in the planning process of hydropower projects at the national and international level.

**Lecture notes**  
Lecture notes will be available online.

**Literature**  
will be specified in the lecture

**Prerequisites / notice**  
External speakers will be involved to present current topics and projects in Switzerland and abroad.

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**101-0608-00L**  
**Design-Integrated Life Cycle Assessment**  
W  3 credits  2G  G. Habert  

**Abstract**  
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

**Objective**  
The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:
1) Know the methodology of LCA
2) Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3) Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

**Content**  
The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand  
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Part II: Project-based learning  
In the second part, the students will work on their individual project in groups of three. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

**Prerequisite:** Sustainable construction (101-0577-00L). Otherwise a special permission by the lecturer is required.

The students are expected to work out of class as well. The course time will be used by the teachers to answer project-specific questions.

The lecture series will be conducted in English and is aimed at students of master's programs, particularly the departments ARCH, BAUG, ITET, MAVT, MTEC and UWIS.

No lecture will be given during Seminar week.

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**101-0329-00L**  
**Tunnelling III**  
W  4 credits  2G  G. Anagnostou, E. Pimentel, M. Ramoni  

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### Abstract
Deepend the knowledge on selected topics of underground construction as well as learning working out conceptual solutions of complex problems.

### Objective
Lecture: Deepen the knowledge on selected topics of underground construction. 
Exercises: Conceptual solutions of complex problems.

### Content
Caverns: Geometry, construction methods, support. 
Shafts: Construction methods, support. 
Urban tunnelling: Boundary conditions, system choice, alignment, design. 
Field measurements: Principles, monitoring layout, applications, interpretation. 
Cut and cover tunnels: Modelling, design. 
Exercising conceptual solution of complex tunnelling problems based upon discussion of current tunnel cases with particularly demanding problems in small groups.

### Lecture notes
Autographieblätter

### Literature
Empfehlungen

### Prerequisites / notice
Prerequisite: BSc course "Tunnelling", MSc courses "Tunnelling I" and "Tunnelling II".

### Taught competencies
| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | assessed |
| | Analytical Competencies | assessed |
| | Decision-making | assessed |
| | Problem-solving | assessed |

### 101-0200-10L
Research-Focused Project Work ■

<table>
<thead>
<tr>
<th>Objective</th>
<th>W</th>
<th>11 credits</th>
<th>24A</th>
<th>Supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working on a concrete task as preparation for the master’s thesis</td>
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</tbody>
</table>

### Content
The project work is supervised by a professor. The topic is going to be continued as master’s thesis.

### Literature

### Prerequisites / notice

### 101-0139-00L
Scientific Machine and Deep Learning for Design and Construction in Civil Engineering

<table>
<thead>
<tr>
<th>Objective</th>
<th>W</th>
<th>3 credits</th>
<th>4G</th>
<th>M. A. Kraus, D. Griego</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.</td>
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</tbody>
</table>

### Content
Upon completion of the course, the students will be able to:

1. understand main ML background theory and methods
2. assess a problem and apply ML and DL in a computational framework accordingly
3. Incorporating scientific domain knowledge in the SciML process
4. Define, Plan, Conduct and Present a SciML project

### Lecture notes
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

### Literature
Suggested Reading:
- S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016
- Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning

### Prerequisites / notice
Familiarity with MATLAB and / or Python is advised.

### 101-0357-00L
Theoretical and Experimental Soil Mechanics ■

<table>
<thead>
<tr>
<th>Objective</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>I. Anastasopoulos, R. Herzog, E. Korre, A. Marin, M. Schneider</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of participants is limited to 60 due to the existing laboratory equipment! Students with major in Geotechnical Engineering have priority. Registrations will be accepted in the order they are received.</td>
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</table>

### Abstract
Overview of soil behaviour 
Explanation of typical applications: reality, modelling, laboratory tests with transfer of results to the practical examples
Consolidation theory and typical applications in practice 
Triaxial & direct shear tests: consolidation & shear, drained & undrained response 
Plasticity theory & Critical State Soil Mechanics, Cam Clay 
Application of plasticity theory

### Objective
Extend knowledge of theoretical approaches that can be used to describe soil behaviour to enable students to carry out more advanced geotechnical design and to plan the appropriate laboratory tests to obtain relevant parameters for coupled plasticity models of soil behaviour.
A further goal is to give students the wherewithal to be able to select an appropriate constitutive model and set up insitu stress conditions in preparation for subsequent numerical modelling (e.g. with finite elements).
Overview of soil behaviour
Discussion of general gaps between basic theory and soil response
Stress paths in practice & in laboratory tests
Explanation of typical applications: reality, modelling, laboratory tests with transfer of results to the practical examples
Consolidation theory for incremental and continuous loading oedometer tests and typical applications in practice
Triaxial & direct shear tests: consolidation & shear, drained & undrained response
Plasticity theory & Critical State Soil Mechanics, Cam Clay
Application of plasticity theory

Lecture notes
Printed script with web support
Exercises

Literature
http://geotip.igt.ethz.ch/

Prerequisites / notice
Lectures will be conducted as Problem Based Learning within the framework of a case history
Virtual laboratory in support of 'hands-on' experience of selected laboratory tests

Pre-requisites: Basic knowledge in soil mechanics as well as knowledge of advanced mechanics
Laboratory equipment will be available for 60 students. First priority goes to those registered for the geotechnics specialty in the Masters, 2nd year students then first year students, doctoral students qualifying officially for their PhD status and then 'first come, first served'.

<table>
<thead>
<tr>
<th>101-0520-00L</th>
<th>Project Management: Project Execution to Closeout</th>
<th>W</th>
<th>4 credits</th>
<th>2G</th>
<th>J. J. Hoffman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The course will give Engineering students a comprehensive overview and enduring understanding of the techniques, processes, tool and terminology to manage the Project Triangle (time, cost Quality) and to organize, analyze, control and report a complex project from start of Project Execution to Project Completion. Responsibilities will be detailed in each phase of the execution.</td>
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<tr>
<td>Objective</td>
<td>A student after completing the course will have the understanding of the Project Management duties, responsibilities, actions and decisions to be done during the Execution phase of a complex project.</td>
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<tr>
<td>Literature</td>
<td>Required and suggested reading will be uploaded on weekly basis.</td>
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<tr>
<td>Prerequisites/notice</td>
<td>Prerequisite for this course is course Project Management: Pre-Tender to Contract Execution number 101-0517-01 G, unless otherwise approved by the lecturer.</td>
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<table>
<thead>
<tr>
<th>101-0120-00L</th>
<th>Structural Glass Design and Facade Engineering</th>
<th>W</th>
<th>3 credits</th>
<th>3G</th>
<th>V.-A. Silvestru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The course gives an introduction to structural glass design and related façade engineering aspects. It will focus on the properties of the material glass and glass products, as well as on the structural design of glass elements and their supporting systems and connections.</td>
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<tr>
<td>Objective</td>
<td>After successful completion of the course, students will be able to:</td>
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<td></td>
<td>- Understand and apply the fundamentals of the material glass and glass products, the basic principles for using glass as a load-carrying building material for structural applications and the types of connections used for glass elements;</td>
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<td>- Recognize requirements for glass elements depending on their application area and chose the appropriate glass products and assemblies accordingly;</td>
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<td>- Structurally design out-of-plane loaded glass elements based on available standards, both by hand calculations and specific software applications;</td>
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<td>- Apply selected approaches for the structural design of in-plane loaded glass elements;</td>
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<td></td>
<td>- Select suitable supporting systems (post-and-beam façade, curtain wall, etc.) and connections (point fixings, brackets, etc.) for the glass elements and structurally design them.</td>
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<tr>
<td>Content</td>
<td>This course introduces civil engineering students to structural glass design and related façade engineering aspects. It aims to provide the students the knowledge required in engineering offices to design glass elements but at the same time, the necessary fundamentals for later performing research in this field. To achieve this, the course includes lectures, design exercises and a design project.</td>
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<tr>
<td>Lectures</td>
<td>The lectures will cover the following contents:</td>
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<td></td>
<td>- Production methods and properties of the material glass and glass products and their structurally relevant properties (annealed glass, thermally tempered glass, chemically tempered glass, laminated glass, insulating glass, curved glass);</td>
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<td>- Connection principles and types for glass elements (mechanical fixing, adhesive bonding);</td>
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<td>- Requirements for glass elements depending on the application area (vertical glazing, overhead glazing, walk-on glazing, barrier glazing);</td>
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<td></td>
<td>- Structural design of glass elements based on standards and research results (out-of-plane loaded glass elements and in-plane loaded glass elements);</td>
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<td></td>
<td>- Typologies and design of structural systems for transparent façades;</td>
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<td></td>
<td>- Requirements and functions for transparent facades.</td>
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<tr>
<td>Design exercises</td>
<td>The principles and methods presented in the lectures are practiced with the students in design exercises. Hand calculation methods and their limitations as well as the software for structural glass design SJ Mepla are used for out-of-plane loaded glass elements. For in-plane loaded glass elements, the specifics of numerical calculation procedures are exemplified with the software Abaqus.</td>
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<tr>
<td>Design project</td>
<td>The students will consolidate the knowledge gained in the theory-lectures and in the design exercises by working on a small design task (e.g. a glass canopy, a glass façade, a glass pavilion) in the form of a group work (ideally groups of 2-3 students). Within this task, the students will: conceptually design the structure and selected connection details; identify requirements for the glass elements and define their assembly; structurally design selected glass components, their support systems and their connections. The students will work on the design task in the second half of the semester and will get feedback on their progress in weekly review sessions. At the end of the semester, the groups will submit a project report and give an oral presentation of their projects.</td>
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<tr>
<td>Lecture notes</td>
<td>The lectures are based on lecture slides and handouts.</td>
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</tbody>
</table>
Part 1 - Discovering a modern parallel computing ecosystem

This course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

Prerequisites / notice
Prior knowledge of structural analysis, especially steel structures is necessary. Prior basic knowledge on the method of finite elements is recommended.

101-0250-00L
Solving Partial Differential Equations in parallel

Objective
When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

Content
Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

Part 2 - Developing your own parallel algorithms
- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

Part 3 - Final project
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes
Digital lecture notes, interactive Julia notebooks, online material.

Literature
Links to relevant literature will be provided during classes.

Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

4 credits
W 3G 6th sem

101-0659-01L
Durability and Maintenance of Reinforced Concrete

Objective
After this course you will have profound understanding about:
• the different mechanisms of deterioration of concrete structures, in particular reinforcement corrosion
• the relevant parameters affecting durability of reinforced concrete (cover depth, concrete quality, moisture, etc.)

Furthermore, you will know:
• current engineering approaches for durability design (according to standards) and their limitations
• refined models for durability design and service life predictions
• preventive measures to improve durability (e.g. stainless steel reinforcement, concrete surface coatings, etc.)
• the particular durability challenges with post-tensioned structures and ways to overcome them (electrically isolated tendons)
• methods for inspection and condition assessment of existing, ageing structures (including non-destructive techniques and monitoring with sensors)
• repair methods for deteriorated concrete structures such as conventional repair and electrochemical methods (in particular cathodic protection)
• possible future problems for durability that may arise with modern materials and construction technologies

Content
Socio-economic challenges related to ageing infrastructures
Degradation mechanisms for concrete: sulphate attack, ASR, frost attack.
Inspection and condition assessment: Chloride analyses, carbonation depth, etc. Non-destructive tests, particularly potential mapping to detect corrosion. New developments (for example, monitoring with sensors).
Stainless steel as reinforcing steel for concrete: Different types of stainless steels. Coupling with black reinforcing steel. Examples of application. Life-cycle-costs.
Modern materials and construction technologies: Discussion of expected implications for the durability of structures today and in the future.

Excursion:
• We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

Lecture notes
The course is based on the book Corrosion of steel in concrete - prevention diagnosis repair (WILEY 2013) by L. Bertolini, B. Elsener, P. Pedeleferi and R. Polder

4 credits
W 2V 2nd sem
The course is based on the book

Slides of the lectures will be distributed in advance

Special handouts and reprints for particular topics will be distributed

Form of teaching:
The course is a lecture that contains frequent discussion and interaction between students and lecturer. You will see and work on many examples from engineering practice, both during the lectures and in the form of exercises to be solved at home.

Report:
Each student will work on a small case study and deliver a report during the semester. The report will be graded.

Excursion:
We generally try to organize a site-visit (depending on availability of construction sites). Presumably, we will visit an installation site of cathodic protection on a concrete structure in the Zurich area.

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
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<td></td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
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<td>Domain C - Social Competencies</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Domain D - Personal Competencies</td>
<td>Adaptable and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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101-0677-00L Concrete Technology

Abstract
Opportunities and limitations of concrete technology. Commodity and leading edge specialties.

Objective
Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.

Content
Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as
- self compacting concrete
- fiber reinforced concrete
- fast setting concrete
- fair faced concrete
- recycled concrete
- new research in digital fabrication with concrete

Lecture notes
Slides provided for download.

101-0427-01L Public Transport Design and Operations

Abstract
This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system.
Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:

- General introduction of transport, modes, technologies, system design and line planning for different situations, timetabling and tactical planning, and related mathematical approaches
- Operations, and quantitative support to operational problems, evaluation of public transport systems.

Content

- Basics for line transport systems and networks
- Passenger/Supply requirements for line operations
- Objectives of system and network planning, from different perspectives and users, design dilemmas
- Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

- Planning process, from demand evaluation to line planning to timetables to operations
- Matching demand and modes
- Line planning techniques
- Timetabling principles
- Allocation of resources
- Management of operations
- Measures of realized operations
- Improvements of existing services

Lecture notes

- Lecture slides are provided.

Literature

- Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Taught competencies

<table>
<thead>
<tr>
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101-0524-00L Lean, Integrated and Digital Project Delivery W 4 credits 3G D. Hall

Abstract

This course is an introduction to innovative construction project delivery through three strategies: integrated information, integrated organization, and integrated processes. Students will be introduced to project and production management concepts such as Lean Construction, Building Information Modeling, the Tri-Constraint Method, & Integrated Project Delivery.

The construction industry is continually seeking to deliver High-Performance (HP) projects for their clients. HP buildings must meet the criteria of four focus areas – buildability, operability, usability, and sustainability. The project must be buildable, as measured by metrics of cost, schedule, and quality. It must be operable, as measured by the cost of maintaining the facility for the duration of its lifecycle. It must be usable, enabling productivity, efficiency and well-being of those who will inhabit the building. Finally, it must be sustainable, minimizing the use of resources such as energy and water. Buildings that succeed in all four of these areas can be considered HP projects.

HP buildings require the integration of building systems. However, the traditional methods of planning and construction do not use an integrated approach. Project fragmentation between many stakeholders is often cited as the cause of poor project outcomes and the reason for poor productivity gains in the construction industry. In response, the construction industry has turned to new forms of integration in order to integrate the processes, organization, and information required for high performance projects.

This course investigates emerging trends in the construction industry – e.g., colocation, shared risk/reward contracts, lean construction methods, and use of shared building information models (BIM) for virtual design and construction (VDC) – as a way to achieve HP projects. For integrated processes, students will be introduced to the fundamentals of lean construction management. This course will look at the causes of variability in construction production and teach the theory of lean production for construction. Processes and technologies will be introduced for lean management, such as the last planner system, takt time planning, production tracking, and target value design. For integrated information, students will be introduced to the fundamentals of virtual design and construction, including how to use work breakdown structures and model breakdown structures for building information modeling, and the fundamentals and opportunities for 4D scheduling, clash detection, and “5D and 6D” models. Future technologies emerging to integrate information such as the use of Autodesk Forge will be presented. Students will have the opportunity to discuss barriers in the industry to more advanced implementation of BIM and VDC.

For integrated organization, students will study the limitations of the construction industry to effectively organize for complex projects, including the challenges of managing highly interdependent tasks and generating knowledge and learning within large multi-organizational project teams. One emerging approach in North America known as IPD will be studied as a case example. Students will explore the benefits of certain ‘elements’ of IPD such as project team colocation, early involvement of trade contractors, shared risk/reward contracts, and collaborative decision making.

The course will also include several guest lectures from industry experts to further demonstrate how these concepts are applied in practice. Lecture Presentation slides will be available for viewing and download the day before each lecture.

The class will be presented in a "flipped classroom" environment where students will be required to do readings or watch video before class. In-class activities will act to reinforce and expand upon these primary concepts.

If possible due to COVID restrictions, students will be expected to attend a half-day workshop on the Last Planner System. The date of this workshop will be provided at a later point in time.

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.
### Workshop on Sustainable Building Certification

<table>
<thead>
<tr>
<th>101-0587-00L</th>
<th>Workshop on Sustainable Building Certification</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>D. Kellenberger</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Building labels are used to certify buildings and neighbourhoods in term of sustainability. Many different labels have been developed and can be used in Switzerland (LEED, DGNB, SNBS, Minergie, 2000-Watt-Sites). In this course the differences between the certification labels and its application on 3 emblematic case study buildings will be discussed.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After this course, the students are able to understand and use the different certification labels. They have a clear view of what the labels take into consideration and what they don't.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Three buildings case study will be presented. Different certification schemes, including LEED (American standard), DGNB (German Standard with Swiss adaptation), Label SNBS, MINERGIE-ECO and 2000-Watt-Site (Swiss standards) will be presented and explained by experts. After this overall general presentation and in order to have a closer look to specific aspects of sustainability, students will work in groups and assess during one or two weeks this specific criteria on one of the case studies presented before. This practical hands on the label will end with a presentation and a discussion where we will highlight differences between the labels.</td>
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<tr>
<td><strong>Lecture notes / notice</strong></td>
<td>The slides from the presentations will be made available.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>All documents for certification labels as well as detail plans of the buildings will be available for the students.</td>
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### Structural Design

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<tr>
<th>101-0123-00L</th>
<th>Structural Design</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>P. Ohlbrock, P. Block, J. Schwartz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a realistic road network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication. Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario. Upon completion of the course, the students will:</td>
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<tr>
<td><strong>Objective</strong></td>
<td>1) Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.). 2) Design a road transport network inside the simulation software. 3) Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network. 4) Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure. 5) Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.</td>
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<tr>
<td><strong>Content</strong></td>
<td>In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include: 1) Car following models 2) Lane change models 3) Calibration and validation methodology Specific tasks for the project will include: 1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed. 2) Calibrating and validating the simulation model. 3) Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++. The course will be based on a project that each group of students will build (design, calibrate, analyze and present) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.</td>
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</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecture notes and additional handouts will be provided before the lectures.</td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Additional literature recommendations will be provided at the lectures.</td>
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</tbody>
</table>

### Materials and Constructions

<table>
<thead>
<tr>
<th>101-0527-10L</th>
<th>Materials and Constructions</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>G. Habert, D. Sanz Pont</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Building materials with a special focus on regenerative materials: earth, bio-based and reuse. Sourcing, properties and performance, building envelope integration and detailing, sustainable building construction</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Special focus on regenerative materials: earth, bio-based and reuse The students will acquire knowledge in the following fields: Fundamentals of material performance Introduction to durability problems of building facades Materials for the building envelope: - Overview of structural materials and systems: concrete, steel, wood and bamboo, earth - Insulating materials (bio-based vs conventional) - Air barrier, vapour barrier and sealants - Interior finishing Assessment of materials and components behaviour and performance Solutions for energy retrofitting of (historical) buildings Aspects of sustainability and durability</td>
<td></td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Introduction Sustainable cement and concrete Earth construction Visit Steel and bamboo Timber construction Building physic and conventional insulation Bio-based insulation Finishing Reuse</td>
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</tbody>
</table>

### Course Traffic Engineering

<table>
<thead>
<tr>
<th>101-0587-10L</th>
<th>Traffic Engineering</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>D. Kellenberger</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication. Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario. Upon completion of the course, the students will:</td>
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<tr>
<td><strong>Objective</strong></td>
<td>1) Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.). 2) Design a road transport network inside the simulation software. 3) Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network. 4) Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure. 5) Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include: 1) Car following models 2) Lane change models 3) Calibration and validation methodology Specific tasks for the project will include: 1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed. 2) Calibrating and validating the simulation model. 3) Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++. The course will be based on a project that each group of students will build (design, calibrate, analyze and present) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecture notes and additional handouts will be provided before the lectures.</td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Additional literature recommendations will be provided at the lectures.</td>
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</tbody>
</table>

### Workshop on Sustainable Building Certification

<table>
<thead>
<tr>
<th>101-0587-00L</th>
<th>Workshop on Sustainable Building Certification</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>D. Kellenberger</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Building labels are used to certify buildings and neighbourhoods in term of sustainability. Many different labels have been developed and can be used in Switzerland (LEED, DGNB, SNBS, Minergie, 2000-Watt-Sites). In this course the differences between the certification labels and its application on 3 emblematic case study buildings will be discussed.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After this course, the students are able to understand and use the different certification labels. They have a clear view of what the labels take into consideration and what they don't.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Three buildings case study will be presented. Different certification schemes, including LEED (American standard), DGNB (German Standard with Swiss adaptation), Label SNBS, MINERGIE-ECO and 2000-Watt-Site (Swiss standards) will be presented and explained by experts. After this overall general presentation and in order to have a closer look to specific aspects of sustainability, students will work in groups and assess during one or two weeks this specific criteria on one of the case studies presented before. This practical hands on the label will end with a presentation and a discussion where we will highlight differences between the labels.</td>
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<tr>
<td><strong>Lecture notes / notice</strong></td>
<td>The slides from the presentations will be made available.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>All documents for certification labels as well as detail plans of the buildings will be available for the students.</td>
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</tbody>
</table>
The goal of the course is to introduce the civil engineering students to Structural Design, which is regarded as a discipline that relates structural behavior, construction technologies and architectural concepts. The course encourages the students to understand the relationship between the form of a structure and the forces within it by promoting the development of designed projects.

### Objective
After successfully completing this course the students will able to:
1. Critically question structural design concepts of historical and contemporary references.
2. Use graphic statics and strut-and-tie models based on the Theory of Plasticity to describe the load bearing behavior of structures.
3. Understand different construction technologies and have an awareness of their potential for structural design.
4. Use contemporary digital tools for the design of structures in equilibrium.
5. Design an appropriate structural system for a given design task taking into account architectural considerations.

### Content
The goal of the course is to introduce the civil engineering students to Structural Design, which is understood as a discipline that relates structural behavior, construction technologies and architectural concepts. Hence, the course encourages the students to develop an intuitive understanding of the relationship between the form of a structure and the forces within it by promoting the development of designed projects, in which the static and architectural aspects come together. The course is structured in two main parts, each developed in half of a semester; a mainly theoretical one (including the teaching of graphic statics) and a mainly applied one (focused on the development of a design project by the students using digital form-finding tools).

### Theory

- **Graphic statics** is a graphical method developed by Prof. Karl Culmann and firstly published in 1864 at ETH Zurich. In this approach to structural analysis and design, geometric construction techniques are used to visualize the relation between the geometry of a structure and the forces acting in and on it, represented by geometrically dependent form and force diagrams.

- The course will firstly review the main principles of graphic statics through a series of frontal lectures and discuss the relationship to analytical statics. Graphic statics is then used as an operative tool to design structures in equilibrium based on the lower bound theorem of the Theory of Plasticity. Additionally, the course will introduce contemporary methodologies and tools (parametric CAD software) for the interactive application of equilibrium modelling in the form of short workshops. The students will familiarize with the topic by solving exercises and confronting themselves with simple design tasks.

### Design Project

Specific structural design approaches and design methodologies based on graphic statics and references from construction history will be introduced to the students by means of seminars and workshops. By developing a design project, the students will apply these concepts and techniques in order to become proficient with open design tasks (such as the design of a bridge, a large span hall or a tower). At the end of the semester, the students present their projects to a jury of internal and external critics in a final review. The main criterion of evaluation is the students’ ability to integrate architectural considerations into their structural design.

### Literature

- "Faustformel Tragwerksentwurf" (PhD Holzner)
- "The art of structures, Introduction to the functioning of structures in architecture" (Philippe Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2015, ISBN 978-3-421-04012-1)
Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

Prerequisites /
notice
The project work requires normally 250 to 300 hours of work.

101-0298-01L
Project on Hydraulic Engineering and Water Resources Management
W
9 credits
19A
Supervisors

Abstract
Working on a concrete task in Hydraulic Engineering

Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

101-0398-01L
Project on Geotechnical Engineering
W
9 credits
19A
Supervisors

Abstract
Working on a concrete task in Geotechnical Engineering

Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

101-0498-01L
Project on Transport Systems
W
9 credits
19A
Supervisors

Abstract
Working on a concrete task on Transport Systems

Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

101-0598-01L
Project on Construction and Maintenance Management
W
9 credits
19A
Supervisors

Abstract
Working on a concrete task in Construction Engineering and Management

Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

101-0698-01L
Project on Materials and Mechanics
W
9 credits
18A
Supervisors

Abstract
Working on a concrete task in Materials and Mechanics

Objective
Promote independent, structured and scientific work; learn to apply engineering methods; deepen the knowledge in the field of the treated task.

Content
The project work is supervised by a professor. Students can choose from different subjects and tasks.

Master’s Thesis

Number
Title
Type
ECTS
Hours
Lecturers

101-0010-00L
Master’s Thesis
O
24 credits
51D
Supervisors

Abstract
Only students who fulfill the following criteria are allowed to begin with their master thesis:
- successful completion of the bachelor programme;
- fulfilling of any additional requirements necessary to gain admission to the master programme.

Objective
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

Content
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

Electives

The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

Electives ETH Zurich

Course Catalogue of ETH Zurich

Recommended Electives of Master Programme

Number
Title
Type
ECTS
Hours
Lecturers

363-1065-00L
Design Thinking: Human-Centred Solutions to Real World Challenges
W
5 credits
5G
S. Brusoni

Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Information and application: http://sparklabs.ch/
Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Content
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in a multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

Prerequisites / notice
Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session. Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Abstract
Literature
Lecture notes

Course slides will be made available to students prior to each class.
Course slides will be made available to students.
Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become the examples, most for understanding how they have taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

The learning material, available via https://moodle-app2.let.ethz.ch/, is comprised of:
- Toolbox 'Reader' with an introduction to the lecture course and tool summaries
- Weekly exercise tasks
- Infographics with basic information of each city
- Quiz question for each tool
- Additional reading material
- Interviews with experts
- Archive of lecture recordings
- Reading material will be provided throughout the semester.

Recap of former SDL courses:

In Ostana, a clear connection is between the local identity (culture, traditions, visions) which is formed by Occitan culture (food, music, dance, language), traditional stone building architecture which is under pressure to carefully evolve with new needs for carbon-neutral and net-positive buildings, and the Monte Viso landscape. How does a re-growing economy that should be regenerative and circular by design, correlate with innovation in architecture, with population growth and associated challenges in mobility, waste systems and supplies, with growing tourism, new agro-forestry practices like industrial hemp and Paulownia, while impacts of climate change are clearly visible? How does the community design a vision that is based on cooperation on different governance scales, balancing local identity and urgently needed international innovation?

Deliverables & output: This SDL course RE:GENERATE builds upon related work from former courses hosted and lead by the MonViso Institute (i.e. on social innovation, mobility, architecture and local identity, tourism, circular economy, land use change) to develop and design foundations for an extension of the existing, visualized and partly quantified systems map, that will support ongoing and future innovation processes in this community. The focus now is on the urban integrated into new, regenerative business models of the alpine, and in regenerative relation between both as a model for the future. This course will thus develop an extended graphical systems map from the alpine to the urban, backed up by a technical report, and connected with the existing systems maps of Ostana and the surrounding valley.

see learning materials and https://systemicdesignlabs.ethz.ch/

Autumn Semester 2021
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Literature


Prerequisites / notice

Depending on the Covid situation, some part of the course will be virtual via Zoom, using a Miro design board. If possible, we will do a field trip. Some travel costs may apply.

Students need to be motivated to design in teams on the preparation of the deliverables, a systemic strategy map and a written report.

Taught competencies

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

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

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

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

GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-BAUG.

Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0700-00L</td>
<td>Programming for Engineers</td>
<td>E-</td>
<td>4 credits</td>
<td>4G</td>
<td>to be announced</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Remark: Will only be offered as of HS22.</td>
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</tbody>
</table>

Civil Engineering Master - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Biochemistry – Chemical Biology Bachelor

#### Core Courses First Year Examination

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0011-02L</td>
<td>General Chemistry (Inorganic Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>A. Togni</td>
</tr>
<tr>
<td></td>
<td>Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions</td>
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<tr>
<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.</td>
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<tr>
<td></td>
<td>Literature</td>
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</tbody>
</table>

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0011-03L</td>
<td>General Chemistry (Organic Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>P. Chen</td>
</tr>
<tr>
<td></td>
<td>Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicity, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intramolecular interactions</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt</td>
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<tr>
<td></td>
<td>Literature</td>
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</tbody>
</table>

#### Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Type</th>
<th>Taught</th>
<th></th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A</td>
<td>Subject-specific Competencies</td>
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<td>Domain B</td>
<td>Method-specific Competencies</td>
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<td>Domain C</td>
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<td>Domain D</td>
<td>Personal Competencies</td>
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### Number 529-0011-01L

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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0011-01L</td>
<td>General Chemistry (Physical Chemistry) I</td>
<td>O</td>
<td>3</td>
<td>2V+1U</td>
<td>H. J. Wörner</td>
</tr>
<tr>
<td></td>
<td>Die Vorlesung vermittelt eine Einführung in einige physikalischen Grundlagen der Chemie, insbesondere in die Radioaktivität, die Quantenmechanik, den Aufbau der Materie und eines Atoms, des Periodensystems der Elemente und die chemische Bindung.</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>Die Studierenden sind nach der Vorlesung in der Lage,</td>
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<tr>
<td></td>
<td>- mit für die Chemie wichtigen physikalischen Grössen und deren Einheiten zu rechnen,</td>
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<td></td>
<td>- einige Eigenschaften chemisch relevanter Teilchen zu benennen und experimentelle Methoden zur Bestimmung dieser Eigenschaften vorzuschlagen,</td>
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<tr>
<td></td>
<td>- Anwendungen und Gefahren der Radioaktivität zu benennen,</td>
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<tr>
<td></td>
<td>- radioaktive Zerfallsprozesse zu kategorisieren und den zeitlichen Verlauf von einfachen Zerfallsreaktionen mathematisch wiederzugeben sowie qualitativ vorherzusagen und darzustellen,</td>
<td></td>
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<tr>
<td></td>
<td>- Wellen- und Teilcheneigenschaften von elektromagnetischer Strahlung und Materie zu beschreiben und experimentelle Methoden zu deren Nachweis vorzuschlagen,</td>
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<td></td>
<td>- die Grundlagen der Quantenmechanik (Bedeutung der Wellenfunktion, Heisenberg'sche Unschärferelation, Operatoren, Kommutatoren) zu erklären und einfache Rechnungen damit auszuführen,</td>
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<td></td>
<td>- Absorptions- und Emissionsspektren von Einlektronenatomen zu analysieren und zu berechnen,</td>
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<td></td>
<td>- die Schrödingergleichung für ein molekulares Mehrtelchensystem aufzustellen,</td>
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<td></td>
<td>- die Schrödingerungleichung für die Modelle der Modellsysteme Teilchen im Kasten und harmonischer Oszillator in einer Dimension selbstständig zu lösen und auf höherdimensionale nicht-wechselwirkende Probleme zu verallgemeinern,</td>
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<tr>
<td></td>
<td>- Molekülschwingungen von zweiatomigen Molekülen mit dem Modell des harmonischen und des anharmonischen Oszillators zu modellieren,</td>
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<td></td>
<td>- das Konzept eines Orbitals zu erklären und die qualitative Form der Orbitale des Wasserstoffatoms mathematisch und bildlich wiederzugeben,</td>
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<td></td>
<td>- den Aufbau des Periodensystems der Elemente mit Hilfe des Orbitalkonzepts zu erklären,</td>
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<td></td>
<td>- Ähnlichkeiten in der elektronischen Struktur von Atomen zu erkennen und zu benutzen, um chemisch relevante Eigenschaften vorhersagen, und</td>
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<tr>
<td></td>
<td>- Termssymbole für atomare Grundzustände aufzustellen.</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.</td>
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<td></td>
<td>Lecture notes</td>
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<td>See homepage of the lecture.</td>
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<tr>
<td></td>
<td>See homepage of the lecture.</td>
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**Data: 14.12.2021 12:41**

**Autumn Semester 2021**

**Page 229 of 2152**
551-0125-00L  
Fundamentals of Biology I: From Molecules to the Biochemistry of Cells  
Abstract: The lecture provides an introduction to the basics of biochemistry and molecular biology as well as evolutionary principles. The focus is on bacteria and archaea under consideration of universal concepts. The lecture introduces biology as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:
1. Geochemical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

Objective: Introduction to calculus in one dimension. Building simple models and analysing them mathematically.

Content:
- Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.
- Functions of one variable: introduction to calculus in one dimension. Building simple models and analysing them mathematically.


401-0271-00L  
Mathematical Foundations I: Analysis A  
Abstract: Introduction to calculus in one dimension. Building simple models and analysing them mathematically. Further reading suggestions will be indicated during the lecture.

Objective: Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.

Content: Functions of one variable: introduction to calculus in one dimension. Building simple models and analysing them mathematically.

Literature:
- G. B. Thomas, M. D. Weir, J. Hass: Analysis 1, Lehr- und Übungsbuch, Pearson-Verlag
- R. Sperb/M. Akveld: Analysis I (vdf)
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg

529-0001-00L  
Introduction to Computer Science  
Abstract: Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation.

Objective: Acquire a starting package concerning the computational aspects of natural sciences; discuss fundamentals of computer architecture, languages, algorithms and programming with an eye to their application in the area of chemistry, biology and material science.

Content: Lecture: Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation; Exercises: Make students familiar with the UNIX operating system, C++ programming techniques, simple algorithms and computational applications in chemistry by means of exercise series at the computer.

Lecture notes: Script booklet (copies of powerpoint slides, in English), distributed at first or second lecture.

Literature: See: www.csms.ethz.ch/education/Infol
### Second and Third Year Core Courses

#### Examination Blocks

##### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>529-0121-00L</td>
<td>Inorganic Chemistry I</td>
<td></td>
<td></td>
<td></td>
<td>H. Grützmacher, P. Steinegger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals as well as the lanthanides and actinides. Introduction of methods of characterization, physical-chemical properties of coordination compounds as well as principles of radiochemistry.</td>
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<tr>
<td>Objective</td>
<td>The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. The students will acquire knowledge on the fundamentals of radioactive decay and radiochemistry. Furthermore, they will be familiar with the basics of inorganic chemistry of lanthanides and actinides.</td>
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<tr>
<td>Content</td>
<td>This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides: 1) General definitions and terms in coordination chemistry; 2) Coordination numbers and structures; 3) Ligand types; 4) The chemical bond in coordination compounds part A: Crystal field theory and ligand field theory; 5) The chemical bond in coordination compounds part B: Qualitative MO theory; 6) Reactivity and reaction mechanisms of coordination compounds; 7) Group theory and character tables; 8) Properties and characterization of coordination compounds; 9) Introduction to radiochemistry; 10) Principles of the chemistry of the lanthanides and actinides.</td>
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<tr>
<td>Literature</td>
<td>Eine kommentierte Foliensammlung ist im HCI-Shop erhältlich.</td>
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</table>

##### Taught competencies

- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Domain B - Method-specific Competencies
  - Analytical Competencies: not assessed
  - Decision-making: not assessed
  - Media and Digital Technologies: not assessed
  - Problem-solving: assessed
  - Project Management: not assessed
- Domain C - Social Competencies
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed
- Domain D - Personal Competencies
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0221-00L</td>
<td>Organic Chemistry I</td>
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<td>H. Wennemers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.</td>
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<tr>
<td>Objective</td>
<td>Acquisition of a basic repertoire of synthetic methods including important reactions of aldehydes, ketones, carboxylic acids and carboxylic acid derivatives, as well as eliminations and fragmentations. Particular emphasis is placed on the understanding of reaction mechanisms and the correlation between structure and reactivity. A deeper understanding of the concepts presented during the lecture is reached by solving the problems handed out each time and discussed one week later in the exercise class.</td>
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<tr>
<td>Content</td>
<td>Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.</td>
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<tr>
<td>Literature</td>
<td>A pdf file of the printed lecture notes is provided online. Supplementary material may be provided online.</td>
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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
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<tr>
<td>529-0422-00L</td>
<td>Physical Chemistry II: Chemical Reaction Kinetics</td>
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<td>F. Merkt, U. Hollenstein</td>
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<tr>
<td>Objective</td>
<td>Introduction to Chemical Reaction Kinetics</td>
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</tbody>
</table>
402-0043-00L  Physics I  O  4 credits  3V+1U  J. Home

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids) Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book “Physics” by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

401-0643-13L  Statistics II  O  3 credits  2V+1U  M. Kalisch

Abstract
Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

Objective

529-0051-00L  Analytical Chemistry I  O  3 credits  3G  D. Günther, M.-O. Ebert, G. Schwarz, R. Zenobi

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

Content
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods: Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling. IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.

Lecture notes
Script will be for the production price

Literature
- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995

Prerequisites / notice
Excercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

535-0521-00L  Pharmacology and Toxicology I  O  2 credits  2V  U. Quitterer, J. Abd Alla

Abstract
The two-semester lecture course will provide a detailed understanding of the fundamentals of drug action and the mechanisms of action and therapeutic use of the important classes of drugs. The lectures are intended for students of pharmaceutical sciences.

Objective
The lectures will provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects.

Content
Topics include disease-relevant macroscopic, microscopic, pathobiochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicity, contraindications and dosage of relevant drug classes. Basic principles of clinical pharmacology and pharmacotherapy will be covered.

Lecture notes
A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.

Literature
Recommended reading:

The classic textbook in Pharmacology:
Goodman and Gilman’s The Pharmacological Basis of Therapeutics

Prerequisites / notice
Voraussetzungen: Abschluss Grundstudium

Examination Block 2
Starting Autumn Semester 2022.

Laboratory Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0124-00L</td>
<td>BCB I: General Chemistry</td>
<td>O</td>
<td>6</td>
<td>8P</td>
<td>H. V. Schönberg</td>
</tr>
</tbody>
</table>
Abstract
Qualitative Analyse (Kationen- und Anionennachweis), Säure-Base-Gleichgewicht (pH-Wert, Titrationen, Puffer), Fällungsgleichgewichte (Gravimetrie, Potentiometrie, Leitfähigkeit), Redoxreaktionen (Synthese, Redoxtitrationen, galvanische Elemente), Metallkomplexe (Synthese, komplexometrische Titration)

Objective
Qualitative Analyse (einfacher Kationen- und Anionentrennungsgang, Nachweis von Kationen und Anionen), Säure-Base-Gleichgewicht (Säure- und Basenstärke, pH- und pKa-Werte, Titrationen, Puffer, Kjeldahlbestimmung), Fällungsgleichgewichte (Gravimetrie, Potentiometrie, Leitfähigkeit), Oxidationszahlen und Redoxverhalten (Synthese), Redoxtitrationen, galvanische Elemente), Metallkomplexe (Synthese von Komplexen, Ligandaustauschreaktionen, Komplexometrische Titration)

Content

Lecture notes
http://www.gruetzmacher.ethz.ch/education/labcourses

Literature
https://moodle-app2.let.ethz.ch

Prerequisites / notice
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

529-0016-00L BCB III: Organic Chemistry O 8 credits 12P J. W. Bode

Abstract
Laboratory course in Organic Chemistry for students of "Biochemistry - Chemical Biology"

Objective
Introduction into basic techniques used in the organic laboratory. Understanding organic reactions through experiments.

Content
Part I: Basic operations such as the isolation, purification, and characterization of organic compounds: distillation, extraction, chromatography, crystallization, IR (UV/1H-NMR)-spectroscopy for the identification of the constitution of organic compounds.

Part II: Organic reactions: preparative chemistry. From simple, one-step to multi-step syntheses. The syntheses include classic Organic Chemistry as well as methods widely used in a Chemical Biology context.

Lecture notes
see https://bode.ethz.ch/education/bcb-iii/bcb-iii-lab-course.html

Literature

Prerequisites / notice
Basisprüfung + BCB I: General Chemistry

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving not assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking not assessed
Critical Thinking not assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

Block Courses
Starting Autumn Semester 2022

Electives
Course offerings from 3. year on (starting autumn semester 2022)

GESS Science in Perspective

Science in Perspective
see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

Language Courses
see Science in Perspective: Language Courses ETH/UZH

Biochemistry – Chemical Biology Bachelor - Key for Type

<table>
<thead>
<tr>
<th>W</th>
<th>Eligible for credits</th>
<th>Dr</th>
<th>Suitable for doctorate</th>
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<tbody>
<tr>
<td>E</td>
<td>Recommended, not eligible for credits</td>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>Key for Hours</td>
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<td>lecture</td>
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<td>practical/laboratory course</td>
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<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Introductory Course in Neuroscience I (University of Zurich)

**No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.**

**UZH Module Code: SPV0Y005**

**Mind the enrolment deadlines at UZH:**

**Abstract**

The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

**Objective**

The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.

**Content**

1) Human Neuroanatomy I&II  
2) Comparative Neuroanatomy  
3) Building a central nervous system I&II  
4) Synapses I&II  
5) Glia and more  
6) Excitability  
7) Circuits underlying Emotion  
8) Visual System  
9) Auditory & Vestibular System  
10) Somatosensory and Motor Systems  
11) Learning in artificial and biological neural networks

**Prerequisites / notice**

For doctoral students of the Neuroscience Center Zurich (ZNZ).

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### Rate-Controlled Separations in Fine Chemistry

**Abstract**

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.

**Objective**

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

**Content**

The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

**Lecture notes**

Handouts during the class

**Literature**

Recommendations for text books will be covered in the class

**Prerequisites / notice**

Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

---

### Applied Statistical Regression

**Abstract**

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

**Lecture notes**

A script will be available.
In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

551-1619-00L Structural Biology

Abstract
The course consists of a series of research seminars on Structural Biology, Biochemistry and Biophysics, given by both scientists of the National Center of Competence in Research (NCCR) in Structural Biology and external speakers. Information on the individual seminars is provided on the following websites:
http://www.structuralbiology.uzh.ch/educ002.asp
http://www.biol.ethz.ch/dbiol-cal/index

Objective
The goal of this course is to provide doctoral and postdoctoral students with a broad overview on the most recent developments in biochemistry, structural biology and biophysics.

851-0180-00L Research Ethics

Abstract
Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective
Participants of the course Research Ethics will:
- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;
I. Introduction to Moral Reasoning

1. Ethics - the basics
1.1 What ethics is not... 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRDP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more...).

Taught competencies
| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | assessed |
| | Problem-solving | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |

376-1581-00L Cancer: Fundamentals, Origin and Therapy

Z 2 credits 2G H. Nägeli

Abstract

Objective
Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.

Content
The lecture deals with problems of tumor epidemiology (causes, mortality, incidence). Cancer is delineated as a multi-step process. Classes of chemical compounds that induce cancer are discussed as well as the reactive metabolites that may be built from. Covalent binding to DNA is discussed and different types of mutations resulting thereof. A selection of proto-oncogenes and tumor suppressor genes is presented. Their function will be discussed as well as the changes which are found in these genes in tumor cells, starting from single nucleotide exchanges up to large deletions.

The reason for genetic predisposition to cancer will be discussed as well as cancer relevant aspects of cell cycle regulation. The role of tumor microenvironments and phenomena like angiogenesis and metastasis are presented as well as the mechanisms that protect the genome from mutagenic damage. Further subjects address old and new strategies of cancer treatment. Personalised cancer treatment. Additional information is given during the lecture.

Literature
Prerequisites / notice
Taught competencies
The lecture requires an active participation of the students. All students will participate in individual or group work focussing on specific subject of the lecture. Students will have ample time for preparation during lecture time.

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

401-5640-00L ZuKoS: Seminar on Applied Statistics
- Z Dr
- 0 credits
- 1K

Abstract
About 5 talks on applied statistics.

Objective
See how statistical methods are applied in practice.

Content
There will be about 5 talks on how statistical methods are applied in practice.

Prerequisites / notice
This is no lecture. There is no exam and no credit points will be awarded. The current program can be found on the web: http://stat.ethz.ch/events/zukost

Course language is English or German and may depend on the speaker.

551-1109-00L Seminars in Microbiology
- Z Dr
- 0 credits
- 2K
- S. Sunagawa, W.-D. Hardt, M. Künzler, J. Piel, J. Vorholt-Zambelli

Abstract
Seminars by invited speakers covering selected microbiology themes.

Objective
Discussion of selected microbiology themes presented by invited speakers.

501-0620-00L Statistical Consulting
- Z Dr
- 0 credits
- 0.1K
- M. Kalisch, L. Meier

Abstract
The Statistical Consulting service is open for all members of ETH, including students, and partly also to other persons.

Objective
Advice for analyzing data by statistical methods.

Content
Students and researchers can get advice for analyzing scientific data, often for a thesis. We highly recommend to contact the consulting service when planning a project, not only towards the end of analyzing the resulting data!

Prerequisites / notice
This is not a course, but a consulting service. There are no exams nor credits.

Contact: beratung@stat.math.ethz.ch . Tel. 044 632 2223. See also http://stat.ethz.ch/consulting

Requirements: Knowledge of the basic concepts of statistics is desirable.

551-0512-00L Current Topics in Molecular and Cellular Neurobiology
- Z Dr
- 2 credits
- 1S
- U. Suter

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

Content
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

You are expected to take part in the discussion and to ask questions. To prepare for this you should read all the papers beforehand (they will be announced a week in advance of the presentation).

Lecture notes
Presentation will be made available after the seminar.

Prerequisites / notice
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).
Seminar series on technical aspects of high-resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules.


This monthly meeting is a platform for Zurich-based immunology research groups to present and discuss their ongoing research projects. At each meeting three PhD students or Postdocs from the participating research groups present an ongoing research project in a 30 min seminar followed by a plenary discussion.

The aim of this monthly meeting is to provide further education for master and doctoral students as well as Postdocs in diverse topics of immunology and to give an insight in the related research. Furthermore, this platform fosters the establishment of science- and technology-based interactions between the participating research groups.

Presentation and discussion of current research projects carried out by various immunology-oriented research groups in Zurich.

none

Progress Reports in Microbiology and Immunology
Students must sign up via secr.micro.biol.ethz.ch

Presentation and discussion of current research results in the field of Microbiology and Infection Immunology

Precise and transparent presentation of research findings in relation to the current literature, critical discussion of experimental data and their interpretation, development and presentation of future research aims

J. Piel, W.-D. Hardt, A. Oxenius, J. Vorholt-Zambelli

This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution.

This compulsory course is required only once. It may be taken in autumn as course 551-0120-00 "Plant Biology Colloquium (Autumn Semester)" or in spring as course 551-0120-01 "Plant Biology Colloquium (Spring Semester)".

Current topics in Molecular Plant Biology presented by internal and external speakers from academia.

Getting insight into actual areas and challenges of Molecular Plant Biology.


This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution.

Introduction and discussion of advanced methods for recording and analysis of NMR data with biological macromolecules.

Seminar series on technical aspects of high-resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules. This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution.

A. D. Gossert

Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107 (use your AAI login)

Domain A - Subject-specific Competencies
Concepts and Theories
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed

Domain C - Social Competencies
Communication
not assessed
Cooperation and Teamwork
not assessed
Self-presentation and Social Influence
not assessed

Domain D - Personal Competencies
Creative Thinking
not assessed
Critical Thinking
assessed
Self-awareness and Self-reflection
not assessed
Self-direction and Self-management
not assessed

Notices

For information, location and details: http://www.tb.ethz.ch/education/zis.html

For information, location and details: http://www.impb.ethz.ch/news-and-events/colloquium-impb.html

Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107 (use your AAI login)

Prerequisites / notice

Domain A - Subject-specific Competencies
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assessed

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Prerequisites / notice

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Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107 (use your AAI login)

Prerequisites / notice

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For information, location and details: http://www.tb.ethz.ch/education/zis.html

For information, location and details: http://www.impb.ethz.ch/news-and-events/colloquium-impb.html

Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107 (use your AAI login)
This course is a seminar series on current research topics within the Institute of Molecular Health Sciences. The course introduces the participants to recent developments in the fields of molecular health sciences. Approval of the responsible lecturer necessary for participation.

Abstract
Lecture Series about topics of space research and exploration consisting of individual talks given by different leading experts from industry and academia.

Objective
Attending students will
• experience the interdisciplinarity of space research and exploration spanning physics, engineering, geosciences, biology and more
• be familiarized with the Swiss space research and industry sector
• improve their communication skills by broadening their research horizon
• have the opportunity for direct learning by posing questions to experts

Content
The field of space research and exploration is intrinsically interdisciplinary. Cutting edge space activities are dominated by an interplay between the scientifically desirable and the technologically possible. The ‘Lecture Series: Space Research and Exploration’ aims to shed light on key questions engaged by leading scientists and engineers today. It consists of weekly lecture, given by different speakers with vast experience in their respective field (e.g., Human Spaceflight, System Engineering of Spacecraft, Space Life Sciences, Space-based astrophysics). Subsequent to the talk, the student will have the opportunity to deepen their understanding by asking questions to the presenter in a moderated Q&A.

Confirmed speakers include:
21.09.: Prof. Sascha P. Quanz (ETH Zürich); Professor for Exoplanets
28.09.: Dr. Anna Kubik (ETH Zürich); Senior Scientist for Orbital Dynamics
12.10.: Dr. Andrea Fortier (University of Bern); CHEOPS Instrument Scientist
19.10.: Prof. Volker Gass (EPFL Lausanne); Director of Space Innovation
26.10.: Dr. Hendrik Kolvenbach (ETH Zürich); Postdoctoral Researcher for Space Robotics
02.11.: Deborah Müller (RUAG Space); Director of Innovation & Business Development
16.11. & 21.12.: Prof. Claude Nicollier (EPFL Lausanne); Professor Emeritus, EPFL and former Astronaut
23.11.: Dr. Adrian Glauser (ETH Zürich); Senior Scientist for Astronomical Instrumentation
30.11.: Prof. Louise Harra (ETH Zürich); Professor of Solar Astrophysics
17.12.: Prof. Didier Queloz (ETH Zürich / Cambridge); Professor for Exoplanets

Biology (General Courses) - Key for Type

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

Key for Hours

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

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The lecture introduces biology as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:
1. Geochemical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

The newly conceived lecture is supported by scripts.

The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.


Further reading:

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

C. Thilgen

- Understanding the basic concepts and definitions of organic chemistry. Knowledge of the functional groups and classes of compounds that are important in biological systems. Foundations for the understanding of the relationship between structure and reactivity.

Lecture notes
Printed lecture notes are available. Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry I" of the current semester (https://moodle-app2.let.ethz.ch).

Literature

Prerequisites / notice
The course consists of lectures (36 hours) and problem-solving lessons (20 hours, groups of ca. 25 people). In addition, online exercises are available in the e-learning environment Moodle (Course OC I).

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | not assessed |
| Domain D - Personal Competencies | Creative Thinking | not assessed |
| | Critical Thinking | not assessed |
| | Integrity and Work Ethics | not assessed |
| | Self-awareness and Self-reflection | not assessed |
| | Self-direction and Self-management | not assessed |

First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0073-00L</td>
<td>Physics I</td>
<td>O</td>
<td>3</td>
<td>2V+2U</td>
<td>T. M. Ihn</td>
</tr>
</tbody>
</table>

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics and elements of quantum mechanics

Objective
Students know and understand the basic ideas of the scientific description of nature. They understand the fundamental concepts and laws of mechanics and they are able to apply them in practical problems. They know the concepts of quantization and quantum numbers.

Content
1. Description of Motion
2. The laws of Newton
3. Work and energy
4. Collision problems
5. Wave properties of particles
6. The atomic structure of matter

Lecture notes
T. Ihn: Physics for Students in Biology and Pharmaceutical Sciences (unpublished lecture notes)

Literature

Feynman, Leighton, Sands, "The Feynman Lectures on Physics", Volume I (http://www.feynmanlectures.caltech.edu/)

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Cooperation and Teamwork | not assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |
| | Self-awareness and Self-reflection | not assessed |
| | Self-direction and Self-management | not assessed |

401-0291-00L Mathematics I

Abstract
Mathematics I/II is an introduction to one- and multidimensional calculus and linear algebra emphasizing on applications.

Objective
Students understand mathematics as a language for modeling and as a tool for solving practical problems in natural sciences. Students can analyze models, describe solutions qualitatively or calculate them explicitly if need be. They can solve examples as well as their practical applications manually and using computer algebra systems.
## Eindimensionale diskrete Entwicklungen ##
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsrate
- Folgen und Grenzwerte

## Funktionen in einer Variablen ##
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

## Differentialrechnung (I) ##
- Veränderungsrate/-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

## Integralrechnung (I) ##
- Stammfunktionen
- Integrationstechniken

## Gewöhnliche Differentialgleichungen (I) ##
- Qualitative Beschreibung an Beispielen:
  - Beschränkt, Logistisch, Gompertz
  - Stationäre Lösungen
  - Lineare DGL 1. Ordnung
  - Trennung der Variablen

## Lineare Algebra ##
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- Quadratische LGS und Determinante

Lecture notes
In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:
* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

Literature
Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Mathematik für Naturwissenschaften, 2 Bände:
Einführung in die Analysis, Einführung in die Lineare Algebra;
Haupt-Verlag Bern, UTB.

**H. H. Storrer**
Einführung in die mathematische Behandlung der Naturwissenschaften I; Birkhäuser.
Via ETHZ-Bibliothek: https://link.springer.com/book/10.1007/978-3-0348-8598-0

**Ch. Blatter**
Lineare Algebra; VDF
auch als [pdf](<https://people.math.ethz.ch/~blatter/linalg.pdf>)

Prerequisites / notice

### Übungen und Prüfungen ###
+ Die Übungsauflagen (inkl. Multiple-Choice) sind ein wichtiger Bestandteil der Lehrveranstaltung.
+ Es wird erwartet, dass Sie mindestens 75 % der wöchentlichen Serien bearbeiten und zur Korrektur einreichen.
+ Der Prüfungstoff ist eine Auswahl von Themen aus Vorlesung und Übungen. Für eine erfolgreiche Prüfung ist die konzentrierte Bearbeitung der Aufgaben unerlässlich.

#### First Year Laboratory Courses ####

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>535-1001-00L</td>
<td>Laboratory Course General Chemistry (for Biology and Pharmacy)</td>
<td>O</td>
<td>6 credits</td>
<td>8P</td>
<td>S. Gruber, K.-H. Altmann, J. Hall</td>
</tr>
</tbody>
</table>

**Abstract**
Information about the practical course will be given on the first day.

Register in myStudies as early as possible, because the fire protection courses take place separately before the internship starts.

**Objective**
- Knowledge of the basic chemical laboratory methods
- Basic knowledge of the scientific approach in experimenting
- Observation and interpretation of chemical processes
- Keeping of a laboratory journal
Content
- Simple chemical working techniques/methods
- Separation techniques
- Physical measurements: mass, volume, pH
- Ionic solids (salts)
- Acid/base chemistry, buffers
- Redox reactions
- Metal complexes
- Titration methods and quantitative spectrometry
- Introduction to qualitative analysis

Lecture notes
Course manual in German (is handed out to the students at the begin of the lessons)
Language: German, English upon request

Literature
Wiley

is a suitable textbook.

Prerequisites / notice
This practical course causes costs for materials and chemicals. The costs are charged to the students at the end of semester.
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

>>> Second Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be discussed by highlighting common and specific functions in fungi, plants, and animals (including humans).

Objective
1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms have developed to cope with the challenges of complex multicellularity.
2. Students can explain how the internal and external structures of fungi, plants and animals function to support survival, growth, behavior, and reproduction.
3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion, metabolism, proliferation, reproduction, development).
4. Students can describe how a single cell develops from one cell into many, each with different specialized functions.

Content
The lecture introduces the structural and functional specialization in fungi, plants and animals, including humans. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi, plants, animals and humans have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism development, and regeneration. Topics include form and function of fungi and plants, human anatomy and physiology, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

Literature
Campbell ‘Biology’, 11th Edition

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1005-00L</td>
<td>Bioanalytics</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>P. Picotti, F. Allain, V. Korkhov, M. Pilhofer, R. Schlapbach, K. Weis, K. Wüthrich, further lecturers</td>
</tr>
</tbody>
</table>

Abstract
The course will introduce students to a selected set of laboratory techniques that are foundational to modern biological research.

Objective
For each of the techniques covered in the course, the students will be able to explain:

a) the physical, chemical and biological principles underlying the technique,
b) the requirements for the sample,
c) the type of raw data collected by the technique,
d) the assumptions and auxiliary information used in the interpretation of the data and
e) how these data can be used to answer a given biological question.

By the end of the course the students will be able to select the appropriate experimental technique to answer a given biological problem and will be able to discuss the advantages and limitations of individual techniques as well as how different techniques can be combined to gain a more complete understanding of a given biological questions.

Content
The course will be based on a combination of lectures, self-study elements and exercises.

The focus will be on the following experimental techniques:
- DNA sequencing
- chromatography
- mass-spectrometry
- UV/Vis and fluorescence spectrometry
- light microscopy
- electron microscopy
- X-ray crystallography
- NMR spectroscopy

Lecture notes
The course is supported by a Moodle page that gives access to all supporting materials necessary for the course.
<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domain A - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Analytical Competencies</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain C - Social Competencies</th>
<th>Communication</th>
<th>not assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Adaptability and Flexibility</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain D - Personal Competencies</th>
<th>Analysis</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Media analysis</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Multivariate Analysis</td>
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<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>252-0852-00L</th>
<th>Foundations of Computer Science</th>
<th>O 4 credits 2V+2U</th>
<th>L. E. Fässler, M. Dahinden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>The students learn to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>1. The role of computer science in science,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- understand the role of computer science in science,</td>
<td></td>
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<tr>
<td></td>
<td>- to control computer and automate processes of problem solving by programming,</td>
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<tr>
<td></td>
<td>- choose and apply appropriate tools from computer science,</td>
<td></td>
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<tr>
<td></td>
<td>- process and analyze real-world data from their subject of study,</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>- handle the complexity of real-world data.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.</td>
<td></td>
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</tr>
<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</table>

<table>
<thead>
<tr>
<th>401-0643-13L</th>
<th>Statistics II</th>
<th>O 3 credits 2V+1U</th>
<th>M. Kalisch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Vertiefung von Statistikmethoden. Nach dem detaillierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>1. Evaluation of chemical equilibria based on chemical potential</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2. Interpretation of phase diagrams</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Which interactions between molecules are important in living cells</td>
<td></td>
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<tr>
<td></td>
<td>4. Why molecules self-organize into aggregates</td>
<td></td>
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<tr>
<td></td>
<td>5. Which physical-chemical basics determine behavior of biomembranes</td>
<td></td>
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<tr>
<td></td>
<td>6. What determines the rate of chemical reactions, in particular also of enzymatically catalyzed reactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. What determines the transport rate of matter and heat</td>
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</tr>
<tr>
<td>Publishing</td>
<td>A lecture script is provided</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>529-0015-00L</th>
<th>Physical Chemistry</th>
<th>O 3 credits 2V+1U</th>
<th>G. Jeschke, D. Klose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Thermodynamic foundations of phase equilibria, intermolecular interactions, and molecular self-assembly; kinetics of chemical reactions and transport processes</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>This course teaches physical-chemical foundations of important processes in living cells and organisms as well as of working techniques in biochemistry and molecular biology. Students learn:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>chemical potential, prediction of the direction of processes, phase equilibria, phase rule, phase diagrams of pure substances, colligative properties, osmosis, dialysis, surface tension, intermolecular interactions, hydrophobic effect, hydrophilic effect and denaturation, amphiphiles, basics of self-association, micelles, packing parameter, double layers, vesicles, membranes, elementary reactions, parallel reactions, consecutive reactions, Eyring theory, enzyme kinetics, diffusion, heat conduction, active transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Publishing</td>
<td>A lecture script is provided</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to the lecture script, the following two books can be used to gain deeper understanding:


Jacob Israelachvili, Intermolecular and Surface Forces, Academic Press, 1992

Taught competencies

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

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

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

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

Abstract
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).

Objective
Learn the basic techniques for the preparation and purification of organic compounds.

Deepen the understanding of reaction mechanisms.

Content
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to C=C, 3. electrophilic aromatic substitution, 4. oxidation, 5. reduction, 6. Grignard reaction, 7. synthesis of a carboxylic acid derivative, 8. Aldol-, Claisen-, Mannich-, Michael reaction or Robinson annulation.

Introduction to database searches (Reaxys, SciFinder).

Lecture notes
Documentation will be handed out at the beginning of the course.

Literature
1) P. Wörfel, M. Bitzer, U. Claus, H. Felber, M. Hübel, B. Vollenweider, Laborpraxis (Bd. 1: Einführung, allgemeine Methoden; Bd. 2: Messmethoden; Bd. 3: Trennungsmethoden; Bd. 4: Analytische Methoden); Birkhäuser Verlag; Basel; 1990.

Prerequisites / notice
The basic reactions of Organic Chemistry and their mechanisms should be known (cf. course 529-1012-00L Organic Chemistry II for Students of Biology, Pharmaceutical Sciences, and Health Sci. and Tech.).

As a prerequisite, all participants need to pass the "Safety Test HCI Chemie_V2 English" (see https://moodle-app2.let.ethz.ch). A printout of the certificate generated by the system needs to be presented to the teaching assistants prior to starting lab work.

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

Bachelor Studies (Programme Regulations 2013)

2. Year, 3. Semester

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0229-00L</td>
<td>Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)</td>
<td>O</td>
<td>8 credits</td>
<td>12P</td>
<td>C. Thilgen, Y. Yamakoshi</td>
</tr>
</tbody>
</table>

The course will teach the basis and typical applications of methods for the analysis of nucleic acid sequences, mass spectrometric analysis of proteins and proteomes and advanced light and fluorescent imaging methods.

Objective
Knowledge of the theoretical basis of the methods for nucleic acid sequence analysis, mass spectrometry based protein and proteome analysis and advanced light and fluorescent imaging methods, and an understanding of the application of these principles in experimental biology.

Content
The course will consist of lectures covering the theoretical and technical base of the respective analytical methods and exercises where typical applications of the methods in modern experimental biology are discussed.

Lecture notes
Materials supporting the lectures and exercises will be made available via Moodle.

401-0643-13L
Statistics II

Objective
Verifivation von Statistikmethoden. Nach dem detaillierteren Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

Objective

Lecture notes
none

Literature
mandatory: "Biochemistry", Autoren: Berg/Tymoczko/Stryer, Palgrave Macmillan, International edition (the English version will be preordered at the Polybuchhandlung)

Prerequisites / notice
Some of the lectures are given in the English language.

551-1323-00L
Fundamentals of Biology II: Biochemistry and Molecular Biology

Objective
The course provides an introduction to Biochemistry / Molecular Biology with some emphasis on chemical and biophysical aspects.

Objective
Topics include the structure-function relationship of proteins / nucleic acids, protein folding, enzymatic catalysis, cellular pathways involved in bioenergetics and the biosynthesis and breakdown of amino acids, glycans, nucleotides, fatty acids and phospholipids, and steroids. There will also be a discussion of DNA replication and repair, transcription, and translation.

Lecture notes
none

Literature

Prerequisites / notice
Some of the lectures are given in the English language. Certain sections of the text-book must be studied by self-instruction.

551-1003-00L
Methods of Biological Analysis

Abstract
The course will teach the basis and typical applications of methods for the analysis of nucleic acid sequences, mass spectrometric analysis of proteins and proteomes and advanced light and fluorescent imaging methods.

Abstract
The goal of the course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students will have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective
The goal of this course is to provide students with a wide general understanding cell biology. With this material as a foundation, students will have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective
The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Lecture notes
The lectures are presented in the Powerpoint format. These are available on the WEB for ETH students over the nethz (Moodle). Some of the lectures are given in the English language.

Prerequisites / notice
Some of the lectures are given in the English language. Certain sections of the text-book must be studied by self-instruction.

529-1023-00L
Physical Chemistry I (for Biology and Pharmacy)

Abstract
This course is offered for the last time in autumn 2021.

Abstract

Prerequisites / notice
Some of the lectures are given in the English language. Certain sections of the text-book must be studied by self-instruction.

Autumn Semester 2021
### Cellular and Molecular Biology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0229-00L</td>
<td>Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)</td>
<td>O</td>
<td>8</td>
<td>12P</td>
<td>C. Thilgen, Y. Yamakoshi</td>
</tr>
</tbody>
</table>

#### Abstract

Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).

Learn to take accurate notes of the experiments and to write reports.

Deepen the understanding of reaction mechanisms.

#### Content

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to C=C, 3. electrophilic aromatic substitution, 4. oxidation, 5. reduction, 6. Grignard reaction, 7. synthesis of a carboxylic acid derivative, 8. Aldol-, Claisen-, Mannich-, Michael reaction or Robinson annulation.

As a prerequisite, all participants need to pass the "Safety Test HCI Chemie_V2 English" (see https://moodle-app2.let.ethz.ch). A printout of the certificate generated by the system needs to be presented to the teaching assistants prior to starting lab work.

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

### Biological Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0229-00L</td>
<td>Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)</td>
<td>O</td>
<td>8</td>
<td>12P</td>
<td>C. Thilgen, Y. Yamakoshi</td>
</tr>
</tbody>
</table>

#### Abstract

Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).

Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).
Lecturers:
The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

As a prerequisite, all participants need to pass the “Safety Test HCI Chemie V2 English” (see https://moodle-app2.let.ethz.ch). A printout of the certificate generated by the system needs to be presented to the teaching assistants prior to starting lab work.

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

Objective
Learn the basic techniques for the preparation and purification of organic compounds.
Learn to take accurate notes of the experiments and to write reports.
Deepen the understanding of reaction mechanisms.

Content
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography).
Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to C=C, 3. electrophilic aromatic substitution, 4. oxidation, 5. reduction, 6. Grignard reaction, 7. synthesis of a carboxylic acid derivative, 8. Aldol-, Claisen-, Mannich-, Michael reaction or Robinson annulation.

Introduction to database searches (Reaxys, SciFinder).

Literature
1) P. Wörfel, M. Bitzer, U. Claus, H. Felber, M. Hübel, B. Vollenweider, Laborpraxis (Bd. 1: Einführung, allgemeine Methoden; Bd. 2: Messmethoden; Bd. 3: Trennungsmethoden; Bd. 4: Analytische Methoden); Birkmhäuser Verlag; Basel; 1990.

Prerequisites / notice
The basic reactions of Organic Chemistry and their mechanisms should be known (cf. course 529-1012-00L Organic Chemistry II for Students of Biology, Pharmaceutical Sciences, and Health Sci. and Tech.).

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competency</th>
<th>Taught</th>
<th>Competency</th>
<th>Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
<td></td>
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<tr>
<td>C</td>
<td>Social Competencies</td>
<td>Communication</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
<td></td>
<td>Negotiation</td>
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<tr>
<td>D</td>
<td>Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
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<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tr>
</tbody>
</table>

Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-2413-00L</td>
<td>Evolutionary Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>T. Städler, A. Widmer, S. Fior, M. C. Fischer, J. Stapley</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
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<td></td>
<td>The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory. Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem. Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Handouts</td>
</tr>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Scripts on the individual topics can be found under <a href="http://www.mol.biol.ethz.ch/teaching">http://www.mol.biol.ethz.ch/teaching</a>.</td>
</tr>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, D. Bopp, A. Hajnal, O. Voinnet</td>
</tr>
<tr>
<td></td>
<td>Information for UZH students:</td>
<td></td>
<td></td>
<td></td>
<td>Enrolment to this course unit only possible at ETH. No</td>
</tr>
</tbody>
</table>

Course: Molecular Life of Plants

**Objective**
This course focuses on the concepts of classical and modern genetics and genomics.

**Content**
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**
Scripts and additional material will be provided during the semester.

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Course: Microbiology (Part I)

**Abstract**
The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

**Objective**
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

**Content**
The course "Molecular Life of Plants" will cover the following topics:

- Plant genome organization and evolution
- Plant functional genomics and systems biology
- Plant genome engineering and editing
- Seed development and embryogenesis
- Root apical meristem: structure, function and hormone regulation
- Shoot apical meristem: structure, function and hormone regulation
- Mobilization of seed reserves
- Heterotrophic to autotrophic growth
- Chloroplast biogenesis and light perception
- Photosynthetic and carbon metabolism
- Integration of carbon and nitrogen metabolism
- Principles of RNA silencing
- MicroRNAs: discovery and modes of action
- RNA silencing and pathogen defense
- RNA silencing movement, amplification and trans-generational silencing
- Plants and the environment
- Plant-pathogen interactions: pathogen attack, first layers of plant defense and plant responses

---

Course: Cellular Biochemistry (Part I)

**Abstract**
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

**Lecture notes**
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

**Literature**
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

**Prerequisites / notice**
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

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

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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

The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data.

Content

Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation
Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice

Course participants have already acquired basic programming skills in Python and R.

Block Courses

Registration for Block courses is mandatory. Please register under https://www.uzh.ch/zoolmed/ssl-dir/Blockkurse_UNIETH.php. Registration period: from 26.07.2021 to 13.08.2021

Please note the ETH admission criteria for the admission of ETH students to ETH block courses on the block course registration website under "allocation".

Block Courses in 1st Quarter of the Semester

From 21.9.2021 to 13.10.2021

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>551-1129-00L</td>
<td>Understanding and Engineering Microbial Metabolism</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>J. Vorholt-Zambelli</td>
</tr>
<tr>
<td>551-1421-00L</td>
<td>The Mechanisms of Natural Transformation in Competent Gram-Negative Bacteria</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>M. Hospenthal</td>
</tr>
</tbody>
</table>

Abstract

This laboratory course has a focus on current research topics in our laboratory related to metabolic engineering, the general understanding of metabolism, and is partially focused on one carbon metabolism. Projects will be conducted in small groups.

Objective

The course aims at introducing technologies to investigate bacterial metabolism and key principles of metabolic engineering. The main focus of this block course is on practical work and will familiarize participants with complementary approaches, in particular genetic, biochemical and analytical techniques including metabolomics. Results will be presented by students in scientific presentations. Another goal is to learn how to write a scientific report.

Content

The course and will include topics such as pathway elucidation & engineering and related ongoing research projects in the lab.

Experimental work applied during the course will comprise methods such as cloning work & transformation, growth determination, enzyme activity assays, liquid-chromatography mass-spectrometry and dynamic labeling experiments.

Lecture notes

None

Literature

Will be provided at the beginning of the course.

General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich.
Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
-Whenever possible the distance rules have to be respected
-All students have to wear masks throughout the course. Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
-The installation and activation of the Swiss Covid-App is highly encouraged
-Any additional rules for individual courses have to be respected
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract

Students will carry out defined research projects related to the current research topics of the Hospenthal group. The topics will include protein expression of pilins and/or other competence proteins from Gram-negative bacteria, protein purification using affinity chromatography, crystallisation experiments and analysis of assembled pili by electron microscopy.

Objective

The course should enable students to understand concepts of protein expression, purification and the characterisation of biomolecular interactions. In addition, students will learn some basic principles of X-ray crystallography and electron microscopy.

Content

The students will be tutored in their experimental work by an experienced doctoral student. The course will also include a short lecture delivered by M. Hospenthal, providing the theoretical background for the experimental work. Throughout the course, students will receive exercises that further help to explain the theory of the practical work, as well as literature research tasks.

Participation in the following Hospenthal lab projects will be possible:
• Purification, biophysical characterisation and structure determination of pilins
• Purification, biophysical characterisation and structure determination of proteins and protein complexes involved in natural transformation.

Experimental work on this project involves:
• Cloning and mutagenesis
• Recombinant or endogenous protein production in E. coli or Legionella
• Protein purification by affinity chromatography (other chromatographic purification techniques will also be discussed)
• Protein crystallisation and crystal optimisation
• Visualisation of bacterial pili by electron microscopy (negative stain or cryo electron microscopy)
• DNA binding experiments
• Enzymatic activity measurements
• In silico structural analyses using PyMOL and Chimera

Prerequisites / notice

There are no special requirements for this course.

551-1415-00L Image-Based Drug Screening in Human Blood for Personalized Medicine

Number of participants limited to 6.

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich. Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
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-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract

Image based screening allows to measure in high throughput the phenotype of millions of individual cells to external perturbations. We have recently shown that image-based screening in human blood can help to find active treatments for patients with blood cancers. In this course we will take the students through the entire workflow (to the extent that biosafety regulations allow it).

Objective

Take the students through the entire workflow from experimental design, to screen, to imaging and analysis.
-Learn to design an image-based screening experiment
-Observe human blood sample handling
-Perform immunofluorescence & automated confocal microscopy
-Image analysis and result interpretation
-Result presentation

Literature

- Relevant study: https://www.thelancet.com/journals/lanhae/article/PIIS2352-3026(17)30208-9/fulltext
- Editorial commentary: https://www.thelancet.com/journals/lanhae/article/PIIS2352-3026(17)30213-2/fulltext

551-0337-00L Cell Biology of the Nucleus

Number of participants limited to 18.

The enrolment is done by the D-BIOL study administration.
General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich.
Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
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Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
-The installation and activation of the Swiss Covid-App is highly encouraged
-Any additional rules for individual courses have to be respected
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
Introduction to the organizational principles of the nucleus using budding yeast, drosophila and vertebrate cells as model systems.

Objective
The aim of our course is to introduce the students to the organizational principles of the nucleus using budding yeast, drosophila and vertebrate cells as model systems. Emphasis is given to:
• Establishment of nuclear identity and nuclear-cytoplasmic communication
• Reorganization of the nucleus in aging
• Animal cells during the generation of cell diversity and neuronal differentiation

By the end of the course, based on lectures, literature reading and practical lab work, the students will be able to formulate open questions concerning the function of the nucleus. Thus, the students will know about the mechanisms and consequences of nuclear-cytoplasmic compartmentalization, nuclear positioning, DNA clustering in the nucleus and cytoplasm during cell divisions and aging.

Content
During this block-course, the students will:
- learn how organelles establish and maintain identity with a focus on the nucleus
- discover the evolutionary and functional plasticity of the nucleus
- design, apply, evaluate and compare experimental strategies

Student - in groups of 2 or max. 3 - will be integrated into a research project connected to the subject of the course, within one of the participating research groups.

Lectures and technical notes will be given and informal discussions held to provide you with the theoretical background.

Literature
Documentation and recommended literature (review articles) will be provided during the course.

Block Courses in 2nd Quarter of the Semester
From 14.10.2021 bis 5.11.2021

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0345-00L</td>
<td>Mechanisms of Bacterial Pathogenesis</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>W. D. Hardt, B. Nguyen</td>
</tr>
</tbody>
</table>

Number of participants limited to 9 in the 2nd semester quarter of the autumn semester.

Number of participants limited to 6 in the 4th semester quarter of the autumn semester.

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich.
Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
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-All students have to wear masks throughout the course.
Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
-The installation and activation of the Swiss Covid-App is highly encouraged
-Any additional rules for individual courses have to be respected
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
Research laboratory class in small groups. Research projects on current topics in cellular microbiology and bacterial pathogenesis are assigned to each student.

Objective
Introduction to a current topic in cellular microbiology and/or molecular genetics of a bacterial pathogen. Experimental work in the research lab and introduction to the current lab techniques. Work with the current research literature in bacterial pathogenesis. Writing of a research protocol.

Requirement for obtaining the credit points: oral presentation of the research project and evaluation of the research protocol.

Content
Research projects on the model pathogen Salmonella.

Lecture notes
none.

Literature
Literature will be selected with reference to the assigned research project.
Introduction of the biological and ecological basics of fungi in forests. Focusing on mycorrhizal, saprobic, and pathogenic fungi and their functional relevance in the forest ecosystems. To get to know current methodological research approaches on the basis of selected examples with practical works in forest and lab as well as excursions and lectures.

**Abstract**

Introduction of the biological and ecological basics of fungi in forests. Focusing on mycorrhizal, saprobic, and pathogenic fungi and their functional relevance in the forest ecosystems. To get to know current methodological research approaches on the basis of selected examples with practical works in forest and lab as well as excursions and lectures.

**Objective**

Knowledge of the fungi of forest and its ecological significance. Knowing of current methodological research approaches. Self-reliant and deepened activities of selected topics of fungi from forests.

**Content**

Introduction of the biological and ecological basics of fungi in forests. Focusing on mycorrhizal, saprobic, and pathogenic fungi and their functional relevance in the forest ecosystems. To get to know current methodological research approaches on the basis of selected examples with practical works in forest and lab as well as excursions and lectures.

**Lecture notes**

Unterlagen zum Kurs werden abgegeben.

**Literature**


**Prerequisites / notice**

Der Blockkurs findet an der Eidg. Forschungsanstalt WSL in Birmensdorf statt. Der Wald vor der Haustüre des Institutes macht diesen Kurs besonders praxisnah.

Erreichbarkeit mit Tram 14 bis Triemli, danach PTT-Bus 220 oder 350 bis Birmensdorf Sternen/WSL, oder mit S9 bis Birmensdorf SBB und mit PTT-Bus eine Station in Richtung Zürich bis Birmensdorf Sternen/WSL.

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The course will introduce the students to the key concepts in membrane biology and will allow them to be involved in laboratory projects related to that broad field. The course will consist of lectures, literature discussions, and practical laboratory work in small groups. Results of the practical projects will be presented during the poster session at the end of the course.

**Abstract**

The course will introduce the students to the key concepts in membrane biology and will allow them to be involved in laboratory projects related to that broad field. The course will consist of lectures, literature discussions, and practical laboratory work in small groups. Results of the practical projects will be presented during the poster session at the end of the course.

**Objective**

The aim of the course is to expose the students to a wide range of modern research areas encompassed by the field of membrane biology.

**Content**

Students will be engaged in research projects aimed at understanding the biological membranes at the molecular, organellar and cellular levels. Students will design and perform experiments, evaluate experimental results, analyze the current scientific literature and understand the relevance of their work in the context of the current state of the membrane biology field.

**Lecture notes**

No script

**Literature**

The recommended literature, including reviews and primary research articles, will be provided during the course.

**Prerequisites / notice**

The course will be taught in English. All general lectures will be held at ETH Hoenggerberg. Students will be divided into small groups to carry out experiments at ETH or at the Paul Scherrer Institute. Travel to the Paul Scherrer Institute will be by public transportation.
General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich.
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Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
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- Any additional rules for individual courses have to be respected
- Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
This course aims to provide students with a comprehensive overview of computational methods for sequence analysis and assist with developing skills for application of computational approaches by experimental scientists in the life sciences.

Objective
Methods for analyzing animal genomes are increasingly becoming important for applications in human health and biotechnology suggesting that the experience will be useful to develop relevant expertise for a broad range of functions. Students will have the opportunity to advance their knowledge in programming by focusing on algorithms for genome and gene sequence analysis. A major goal of the course will be to lead the student to an independent and empowered attitude towards computational problems. For reaching this goal the students will work on an implementation of a solution for a set real-world problem in genome and sequence analysis under guided supervision.

Content
- Understanding the information in biological sequences and quantifying similarity
- Introduction to algorithms for sequence comparison and searches
- Implementation of sequence comparisons and searches in Python
- Accessing data formats associated with genome sequence analysis tasks
- Understanding the anatomy of a real world sequence analysis project
- Applying tools for sequence alignment and estimating error rates
- Ability to implement a solution to a problem in sequence analysis using Python
- Accessing genome annotation and retrieving relevant information in Pandas
- Application of Genomic intervals and arrays for sequence analysis with HTSeq

The course will consist of a series of lectures, assignments for implementing elementary tasks in Python, project development and discussion workshops, and a half week of practical work implementing a Python script as a solution to a real world problem associated with sequence analysis. At the end of the course students will explain their solutions and demonstrate the functionality of their implementations, which will then be discussed and commented on by the group. It is expected that students will be able to apply the knowledge to improve on concrete problems.

Prerequisites / notice
- It is recommended to bring your own computer with a Python installation to the course
- Simple computers can be provided
- Programming basics with Python

551-1143-00L Analysis of Human T and B Cell Responses to Infectious Agents
Number of participants limited to 15.

W 6 credits 7P F. Sallusto, R. Geiger, D. Latorre

The enrolment is done by the D-BIOL study administration.

Abstract
Students actively participate in ongoing research projects on the analysis of human T and B cell response to pathogens and vaccines. They will be tutored in small groups by doctoral students and postdocs. In a lecture series, the theoretical background for the projects will be provided and the students will have the opportunity to present their projects and discuss recent publications.

Objective
To learn current methodologies in human immunology through experimental work in the lab. To learn current concepts through lectures and discussion of original papers. Requirement for obtaining the credit points: oral presentation of the research project in a ppt format.

551-0359-00L Plant Biochemistry
Number of participants limited to 15.

W 6 credits 7P S. C. Zeeman, B. Pfister

The enrolment is done by the D-BIOL study administration.

Abstract

Objective

entitled to attend courses in attendance.
-Whenever possible the distance rules have to be respected.
-All students have to wear masks throughout the course.
Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
-The installation and activation of the Swiss Covid-App is highly encouraged.
-Any additional rules for individual courses have to be respected.
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
In this block course, students actively participate in ongoing research projects on plant metabolism and are tutored by doctoral students and postdocs. The theoretical background of the projects is provided in a lecture series. Finally, students discuss their projects and results during an interactive poster session.

Objective
Through supervision in small groups (either individually or in groups of two) students learn to conduct experiments in molecular plant biology, interpret the results, record them and communicate them to peers. Students also gain an insight into the larger context of their projects and how they are planned in the longer term.

Content
Participation in a project from the following list is possible: 1) Photosynthesis: How is photosynthesis regulated and how is photoassimilated carbon distributed in plants? 2) Biology of chloroplasts: How do chloroplasts develop and how is their function coordinated with that of the whole cell? 3) Starch biosynthesis and degradation: How are complex, semi-crystalline starch granules produced from monosaccharides and how are they broken down again to release energy?

Lecture notes
No script

Literature
Descriptions of the possible projects including individual reading suggestions will be handed out beforehand.

Block Courses in 3rd Quarter of the Semester
From 9.11.2021 to 1.12.2021

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>551-0355-00L</td>
<td>Phytopathology</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>M. Maurhofer Bringolf,</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 12.</td>
<td></td>
<td></td>
<td></td>
<td>B. McDonald</td>
</tr>
</tbody>
</table>

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich.
Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
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-The installation and activation of the Swiss Covid-App is highly encouraged.
-Any additional rules for individual courses have to be respected.
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
Fundamentals (theoretical and practical) in phytopathology, eg. interaction between plants and plant-pathogenic microorganisms, morphology and lifecycles of plant-pathogenic fungi, evolution of plant-pathogenic fungi, biological control of plant diseases.

Objective
Insight into ongoing research projects

Content
Experiments within ongoing phytopathological research projects
Macro- and microscopic diagnostic of plant diseases

Theoretical courses:
Fundamentals of phytopathology, eg. interaction between plants and plant-pathogenic microorganisms, morphology and lifecycles of plant-pathogenic fungi, evolution of plant-pathogenic fungi, biological control of plant diseases

Lecture notes
Teaching language is English and German. Will be distributed at the beginning of the course.

Taught competencies
<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

529-0739-01L Biological Chemistry B: New Enzymes from Directed Evolution Experiments
Number of participants limited to 12.
During the block course in the fall semester, we will carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The class with its very dense program consists of the practical course itself and an integrated series of seminar/lecture sessions.

Objective
All technologies used for the experiments will be explained to the students in theory and in practice with the goal that they will be able to independently apply them for the course project and in future research endeavors. After the course, an individual report about the results obtained has to be prepared.

Content
The class deals with a specifically designed and genuine research project. We intend to carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. By working in parallel, teams of 2 participants each will generate a variety of different variants of a chorismate mutase. Individual enzyme catalysts will be purified and subsequently characterized using several different spectroscopic methods. The detailed chemical-physical analyses include determination of the enzymes’ kinetic parameters, their molecular mass, and the integrity of the protein structure. The results obtained from the individual evolution experiments will be compared and discussed at the end of the class in a final seminar. We expect that during this lab course we will not only generate novel enzymes, but also gain new mechanistic insights into the investigated catalyst.

Literature
General literature to "Directed Evolution" and chorismate mutases, e.g.:


Further literature will be indicated in the distributed script.

Prerequisites / notice
This laboratory course will involve experiments that require a tight schedule and, particularly in the second half, very long (!) working days. The maximum number of participants for the laboratory class is limited, but surplus applicants may contact P. Kast directly to have their names added to a waiting list. A valid registration is considered a commitment for attendance of the entire course, as involved material orders and experimental preparations are necessary and, once the class has started, the flow of the experiments must not be interrupted by individual absences. In case of an emergency, please immediately notify P. Kast. For more information see http://www.kast.ethz.ch/teaching.html, from where you can also download a flyer.

General safety regulations for all block courses:
The COVID certificate is mandatory at ETH Zurich. Only students who have a Covid certificate, i.e. who have been vaccinated, have recovered or have been tested, are entitled to attend courses in attendance.
-Whenever possible the distance rules have to be respected -All students have to wear masks throughout the course. Please keep reserve masks ready. Surgical masks (IIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
-The installation and activation of the Swiss Covid-App is highly encouraged
-Any additional rules for individual courses have to be respected
-Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

Abstract
During the block course in the fall semester, we will carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The class with its very dense program consists of the practical course itself and an integrated series of seminar/lecture sessions.

Methods in Cellular Biochemistry
Number of participants limited to 13.

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:
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**Objective**

Students will learn to design, carry out and assess experiments using current biochemical and cell biological strategies to analyze cellular functions in model systems. In particular they will learn novel imaging techniques along with biochemical approaches to understand fundamental cellular pathways. Furthermore, they will learn to assess strengths and limitations of the different approaches and be able to discuss their validity for the analysis of cellular functions.

**Prerequisites and Literature**

Documentation and recommended literature (review articles and selected primary literature) will be provided during the course.

**Course Information**

- **Number of participants:** limited to 7.
- **Course Format:** The course consists of lectures, seminars, and practical lab projects. Students will perform physiological in vivo studies as well as biochemical experiments.
- **Assessment:** Student assessment is a graded semester performance based on individual performance in the laboratory, a written exam and the lab data presentation.
- **Language:** This course will be taught in English.

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**551-1515-00L Insulin Signaling**

Number of participants limited to 12.

The enrolment is done by the D-BIOL study administration.

**Abstract**

Introduction to the physiological and biochemical action of insulin signaling and its role in the fasted/feeding response and in obesity and diabetes.

**Objective**

The students will obtain an overview about the current topics of research in insulin signaling and how it impacts on growth, metabolism and cell differentiation. They will learn to design experiments and use techniques necessary to analyze different aspects of insulin signaling, including physiological actions in whole animals as well as in tissue culture. Through lectures and literature seminars, they will learn about the open questions of insulin signaling research and discuss approaches to address these questions experimentally.

In practical lab projects the students will perform physiological in vivo studies as well as biochemical experiments. Finally, they will learn how to present and discuss their data. Student assessment is a graded semester performance based on individual performance in the laboratory, a written exam and the lab data presentation.

**Prerequisites**

It is recommended to attend the course Lebensmittel-Mikrobiologie (752-4005-00L) as a preparation. The course can only be booked via the Biology Student secretariat.

**General safety regulations for all block courses:**

- Whenever possible the distance rules have to be respected.
- All students have to wear masks throughout the course. Please keep reserve masks ready. Surgical masks (IIIR) or medical grade masks (FFP2) without a valve are permitted. Community masks (fabric masks) are not allowed.
- The installation and activation of the Swiss Covid-App is highly encouraged.
- Any additional rules for individual courses have to be respected.
- Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.

**Literature**

- Krämer: "Lebensmittel-Mikrobiologie" (Ulmer; UTB)
- Süßmuth et al.: "Mikrobiologisch-Biochemisches Praktikum" (Thieme)

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**752-4020-00L Experimental Food Microbiology for Biologists**

Number of participants limited to 12.

Prerequisites: It is recommended to attend the course Lebensmittel-Mikrobiologie (752-4005-00L) as a preparation.

The course can only be booked via the Biology Student secretariat.

**Abstract**

Teaching of basic experimental knowledge for detection and identification of microorganisms in food. Practical experiments were accompanied by theoretical introductions. Students become acquainted with classical and state-of-the-art molecular techniques for the rapid detection of foodborne pathogens and experiments in dependence on current research topics of the Laboratory of Food Microbiology.

**Objective**

Teaching of basic experimental knowledge for detection and identification of foodborne pathogens by applying state-of-the-art techniques as well as modern molecular techniques for the rapid identification of relevant foodborne pathogens.

**Content**

Teaching of basic experimental knowledge for detection and identification of foodborne pathogens by applying state-of-the-art techniques as well as modern molecular techniques for the rapid identification of relevant foodborne pathogens.

**Lecture notes**

Handouts were provided at the start of the course.

**Literature**

- Krämer: "Lebensmittel-Mikrobiologie" (Ulmer; UTB)
- Süßmuth et al.: "Mikrobiologisch-Biochemisches Praktikum" (Thieme)

**Prerequisites and Literature**

Important information!
During the course we will work with the food-borne pathogen Listeria monocytogenes. Listeria monocytogenes represents a particular threat to pregnant women. Due to biosafety reasons participation is not allowed in case of pregnancy.
The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:
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Abstract
Proteins that seem to have evolved to help stabilize meiosis to temperature and/or polyploidy in plants.

Objective
To learn techniques in protein structure prediction, functional prediction and evolutionary analyses (bioinformatic), as well as protein purification from e. coli, insect cell, and/or cell-free systems, and analysis of e.g. interactions with DNA, thermostability, etc...

Content
Guided research projects to study the biochemical consequences of adaptive evolution in a variety of proteins. Mostly the focus is on proteins that seem to have evolved to help stabilize meiosis to temperature and/or polyploidy in plants.

Lecture notes
Will be provided, as appropriate, during the course.

Literature
Will be provided during course.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1119-00L</td>
<td>Microbial Community Genomics</td>
<td>6</td>
<td>7P</td>
<td>S. Sunagawa</td>
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<tr>
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<td>Number of participants limited to 10.</td>
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<td></td>
<td>Prerequisite: Basic knowledge in [R] (e.g. introductory course) and/or UNIX is required. Participants should bring their own laptop computer.</td>
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</table>

Abstract
Introduction to current research methods in the analysis of microbial communities using Next Generation Sequencing approaches - metagenomics. Practical experience of work in a computational laboratory and an introduction to scientific programming.

Objective
Gain skills in data analysis and presentation for oral and written reports. Lectures introducing state-of-the-art in respective research areas and community microbiology, which is the target of ongoing research. Start to assess current literature.

Prerequisites / notice
Basic knowledge in [R] (e.g. introductory course) and/or UNIX is required. Participants should bring their own laptop computer.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1147-00L</td>
<td>Bioactive Natural Products from Bacteria</td>
<td>6</td>
<td>7P</td>
<td>J. Piel</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 8.</td>
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Highly encouraged
- Any additional rules for individual courses have to be respected
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Abstract
Lab course. In small groups projects of relevance to current research questions in the field of bacterial natural product biosynthesis are addressed.

Objective
Introduction to relevant subjects of the secondary metabolism of bacteria. Training in practical work in a research laboratory. Scientific writing in form of a research report.

Content
Research project on bacteria that produce bioactive natural products (e.g., Streptomycetes, Cyanobacteria, uncultivated bacteria). The techniques used will depend on the project, e.g., PCR, cloning, natural product analysis, precursor feeding studies, enzyme expression and analysis.

Lecture notes
none.

Literature
Will be provided for each of the projects at the beginning of the course.

Block Courses in 4th Quarter of the Semester
From 2.12.2021 to 23.12.2021

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0361-00L</td>
<td>Biology of Bryophytes and Ferns</td>
<td>W</td>
<td>6</td>
<td>7P</td>
<td>R. Holderegger, A. L. Bergamini</td>
</tr>
</tbody>
</table>

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Abstract
Bryophytes: basic knowledge on the morphology, ecology, biogeography and endangerment of byrophytes; knowledge of common species; skills in the determination of bryophytes; field trip.

Ferns: basic knowledge on the life cycle, morphology, evolution and ecology of ferns; identification of Swiss fern species; field trips.

Objective
Bryophytes: basic knowledge on the morphology, ecology, biogeography and endangerment of byrophytes; knowledge of common species; skills in the determination of bryophytes.

Ferns: basic knowledge on the life cycle, morphology, evolution and ecology of ferns; identification of Swiss fern species.

Content
Bryophytes: Systematics and morphology of hornworts, liverworts and mosses and special themes such as ecology, biogeography, diversity and endangerment of bryophytes; one full-day field trip.

Ferns: Life cycle and morphology; evolutionary groups of ferns and lycopods; mating systems, micro- and macroevolution; ecology; full-day and half-day field trips.

Lecture notes
Hand-outs will be distributed.

Literature

Prerequisites / notice
Students have to present a poster on a special theme. Gradate according to poster presentation and contributions during the course.

Requirements: first and second year courses in Botany and Evolution.

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<tr>
<th>Number</th>
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- Students showing any COVID-19 symptoms are not allowed to enter ETH buildings and have to inform the course responsible.
## Introduction to the Diversity of Current RNA Research

### Abstract

Introduction to the diversity of current RNA research at all levels from structural biology to systems biology using mainly model systems like *S. cerevisiae* (yeast), mammalian cells.

### Objective

The students will obtain an overview about the diversity of current RNA research. They will learn to design experiments and use techniques necessary to analyze different aspects of RNA biology. Through lectures and literature seminars, they will learn about the burning questions of RNA research and discuss approaches to address these questions experimentally. In practical lab projects the students will work in one of the participating laboratories. Finally, they will learn how to present and discuss their data in an appropriate manner. Student assessment is a graded semester performance based on individual performance in the laboratory, the written exam and the poster presentation.

### Literature

Documentation and recommended literature will be provided at the beginning and during the course.

### Prerequisites / Notice

The course will be taught in English.

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### Parallels Between Tissue Repair and Cancer

#### 551-1511-00L

| Number of participants limited to 20.
| The enrolment is done by the D-BIOL study administration.

**Abstract**

This course aims at the understanding of the cellular and molecular mechanisms underlying tissue repair processes in response to different insults. The focus will be on repair of the skin and the liver. In addition, we will highlight the parallels and differences between tissue repair and cancer.

**Objective**

To learn the cellular and molecular principles underlying tissue repair processes, in particular in the skin and in the liver, and the parallels and differences to cancer. To learn modern technologies in Molecular and Cellular Biology as well as Histology and to use these technologies to study questions related to mechanisms underlying tissue repair and cancer.

**Content**

This course aims at the understanding of the cellular and molecular mechanisms underlying tissue repair processes in response to different insults. The focus will be on repair of the skin and the liver. In addition, we will highlight the parallels and differences between tissue repair and cancer. Experimental approaches include biochemical studies, molecular and cellular studies using cultured cell lines and primary cells, as well as analysis of murine and human tissues.

The course combines practical work with lectures, discussions, project preparations and presentations.

**Lecture notes**

siehe Lernmaterialien

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### Growth Control and Aging

#### 551-0371-00L

| Number of participants limited to 8.
| The enrolment is done by the D-BIOL study administration.

**Abstract**

Organisms have to control their growth in accordance with environmental conditions. Interestingly, the pathways regulating growth often also affect aging. This course focuses on the analysis of growth regulation in yeast, *Drosophila*, and mammalian cells and on its connection to aging. The participants will perform experiments to study insulin/TOR signaling as a key regulator of growth and aging.
Objective

The aims of the block course are that participants

(I) understand the function and evolution of insulin/TOR signaling

(II) learn how genetic approaches in different organisms contribute to the understanding of complex processes such as aging and cancer in humans

(III) will get familiarized with reading and discussing research articles

(IV) get a first exposure to current research.

Content

The block course consists of

(I) experiments:

Teams of two students each will join research labs to work on current projects focusing on aging and growth regulation in budding yeast, Drosophila and mammalian cells. The students will present their projects and results to their colleagues.

(II) lectures on growth regulation and aging in yeast, Drosophila and mammals.

(III) journal clubs to discuss recent literature.

Lecture notes

Lecture handouts

Literature

Original research articles will be discussed during the course.

551-1403-00L Imaging Bacterial Cells in a Native State by Electron Cryotomography

Number of participants limited to 15.

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:

- The COVID certificate is mandatory at ETH Zurich.
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Abstract

The goal is to acquire the techniques to image bacteria by electron cryotomography, resolving their structure in a native state, in 3D, and to macromolecular resolution. In a small group, students will perform wet lab experiments, data collection with state-of-the-art equipment, data processing and analyses. The key method and its application in bacterial cell biology will be introduced by lectures

https://www.mol.biol.ethz.ch/groups/pilhofer_group/

551-1417-00L In Vivo Cryo-EM Analysis of Dynein Motor Proteins

Number of participants limited to 5.

The enrolment is done by the D-BIOL study administration.

General safety regulations for all block courses:

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- All students have to wear masks throughout the course.
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Abstract

Motor proteins convert chemical energy into mechanical motion. In this block course, we study dynein motor proteins in cilia. Dynein causes conformational change upon ATP hydrolysis and finally generate ciliary bending motion. Participants will analyze cryo-EM data of cilia and visualize in vivo 3D structure of dynein to learn how motor proteins function in the cell.
Objective

The goal of this course is to be familiar with structural biology techniques of cryo-electron tomography and single particle cryo-EM studies on motor proteins. The main focus is 3D image analysis of cryo-EM datasets acquired by highest-end microscopes. Participants will learn structure-function relationship at various scales: how the conformational change of motor proteins causes mechanical force and generates cellular motility.

Content

Motor proteins, such as dynein, myosin and kinesin, hydrolyze ATP to ADP and phosphate to convert chemical energy to mechanical motion. Their function is essential for intracellular transport, muscle contraction and other cellular motility as well as cell division. Motor proteins have been major targets of biophysical studies. There exist questions from atomic to tissue levels – how ATP hydrolysis causes conformational change of motor proteins, how their motion is regulated by calcium, phosphorylation and other factors; how motions of multiple motor proteins are coordinated to generate cellular motility. Structural biology has been playing central roles to answer these questions. X-ray crystallography and single particle cryo-EM address structural analysis at atomic resolution and try to reveal molecular mechanism of conformational change. Cryo-electron tomography analyze localization and 3D structure of motor proteins in the cell to explain how motions of molecular motors happen in the context of cellular environment and are integrated into cellular motion.

In this course, we study dyneins in cilia. Cilia are force-generating organelles, made by nine microtubules and thousands of dyneins. Dynein hydrolyzes ATP and undergoes conformational change, generating linear motion with respect to the microtubule. As a whole system, cilia integrate motions of these dyneins and orchestrate beating motion. To explain ciliary motion at molecular level, we need to know dynein conformational change in the cellular context. Cryo-electron tomography is recently developed technique to study molecular structures in vivo and therefore a suitable method to study dynein in cilia. Recently spatial resolution of these cryo-EM techniques was dramatically improved, driven by development of new types of detectors and electron optics.

The participants of this course will learn a program to analyze cryo-electron tomography and single particle cryo-EM data, acquired by highest-end electron microscopes and detectors in ETH and other places, and reconstruct 3D structure (tomogram) of cilia from various organisms (from green algae to human). They will further learn a program to study molecular structures from these tomograms (called subtomogram averaging) and apply it to reconstruct high-resolution 3D structure of dyneins, microtubules and regulatory proteins. This practical course is therefore mainly computational, but we will also provide students a chance of cilia preparation from green algae, cryo-EM data collection using an electron microscope in PSI and site-visit of highest-end electron microscope facility in ETH.

Lecture notes

Scripts will be distributed during the course.

Literature

An overview is given in the following review articles. Further literature will be indicated during the course.


Abstract

Research laboratory class in small groups. Research projects on current topics in cellular microbiology and bacterial pathogenesis are assigned to each student.

Objective

Introduction to a current topic in cellular microbiology and/or molecular genetics of a bacterial pathogen. Experimental work in the research lab and introduction to the current lab techniques. Work with the current research literature in bacterial pathogenesis. Writing of a research protocol.

Requirement for obtaining the credit points: oral presentation of the research project and evaluation of the research protocol.

Content

Research projects on the model pathogen Salmonella.

Lecture notes

none.

Literature

Literature will be selected with reference to the assigned research project.

Block Courses in the 1st Half of the Semester

From 21.9.2021 to 5.11.2021

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

highly encouraged - Any additional rules for individual
courses have to be respected - Students showing any
COVID-19 symptoms are not allowed to enter ETH
buildings and have to inform the course responsible.

Abstract
This course combines Limnology (the study of inland waters in its broad sense) with ecological and evolutionary concepts. It deals with
rivers, groundwater, and lakes.
This course contains a lecture part, an experimental part, two determination courses (aquatic invertebrates and algae) as well as
excursions.

Objective
During this course you will get an overview of the world's typical continental aquatic ecosystems. After this course you will be able to
understand how aquatic organisms have adapted to their habitat, and how the interactions (e.g. food web) between organisms work.
During the experimental part of this course you will learn the principles of doing research to observe interrelations in aquatic ecosystems.
You will measure and interpret biological and physical data (e.g. during experiments, field work) and present the collected knowledge.
After this course you will know the most important aquatic species groups (macroinvertebrates, microinvertebrates, and freshwater algae) in
Switzerland and the most important identification traits.

Content
The course contains a lecture part, an experimental part, two determination courses (aquatic invertebrates and algae) and field excursions.

Lecture:
The lecture part covers ecology and evolution of aquatic organisms in lentic and lotic waters. Topics include: Adaptations, distribution
patterns, biotic interactions, and conceptual paradigms in freshwater ecosystems; important aspects regarding ecosystem metabolism and
habitat properties of freshwaters; applied case studies and experiments testing ecological and evolutionary processes in freshwaters.

Practical part:
The practical part includes an excursion to Greifensee and a 3-day-excursion to the river Glatt in Niederuzwil, where you independently
perform small research projects.
Additionally, you will perform in small groups an independent experiment in a research group at Eawag.

The taxonomic part will cover macroinvertebrates (e.g. Crustacean, aquatic insects), microinvertebrates and algae. The goal is to get to
know the most common aquatic taxa in Switzerland, to identify them with commonly used identification literature, and to get an idea how
these organisms are used in research and practice. (language: German, translation of the most important things during the course
possible)

Lecture notes
Course notes and power point presentations provided during the course.

Prerequisites / notice
The maximal participating number of biology students is 14.

Block Courses during Semester Break

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>551-1709-00L</td>
<td>Genomic and Genetic Methods in Cell and Developmental Biology</td>
<td>W</td>
<td>6 credits</td>
<td>7P</td>
<td>A. Wutz, M. Kopf, T. Schroeder</td>
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</tbody>
</table>

This course aims to provide students with a comprehensive overview of mammalian developmental biology and stem cell systems both on
the theoretical as well as the experimental level. Centering the course on genetic and genomic methods engages the students in
contemporary research and prepares for future studies in the course of semester and master projects.

Objective
- Understanding mammalian development
- Introduction to stem cells systems
- Working with cultured cells
- Translational aspects of mammalian cell biology

Content
The course will consist of a series of lectures, essay assignments, project development and discussion workshops, and 2 and a half week
of lab work with different mammalian cell systems embedded in real life research projects. At the end of the course students will take an
exam consisting of questions on the topic of the lectures and workshops. It is expected that students will be able to apply the knowledge to
concrete problems.

GESS Science in Perspective

Recommended GESS Science in Perspective (Type B) for
D-BIOL.

see GESS Science in Perspective: Type A: Enhancement
of Reflection Capability
## Language Courses

see GESS Science in Perspective: Language Courses

ETH/UZH

### Biology Bachelor - Key for Type

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

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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Educational Science

Course offerings in the category Educational Science are listed under “Programme: Educational Science for Teaching Diploma and TC”.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<tr>
<td>Objective</td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<tr>
<td></td>
<td>- Get information about recent literature on learning and instruction</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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see Educational Science Teaching Diploma

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<tbody>
<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td></td>
<td>Number of participants limited to 30.</td>
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<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<tr>
<td>Objective</td>
<td>- Understanding of research methods used in the empirical human sciences</td>
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<td></td>
<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tbody>
<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1 credit</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
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<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td>Number of participants limited to 30.</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td>Abstract</td>
<td>Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.</td>
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<tr>
<td>Objective</td>
<td>- Understand research methods used in the empirical educational sciences</td>
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<td></td>
<td>- Understand and critically examine information from scientific journals and media</td>
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<td></td>
<td>- Understand pedagogically relevant findings from the empirical educational sciences</td>
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<tr>
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<tbody>
<tr>
<td>851-0242-11L</td>
<td>Gender Issues In Education and STEM</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
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<tr>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>Number of participants limited to 30.</td>
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<td></td>
<td>Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.</td>
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<tr>
<td>Abstract</td>
<td>In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.</td>
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<tr>
<td>Objective</td>
<td>- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues</td>
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<td>- To develop a critical view on existing research and perspectives.</td>
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<td></td>
<td>- To integrate this knowledge with teacher’s work.</td>
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<tr>
<td>Content</td>
<td>Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.</td>
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<td></td>
<td>The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).</td>
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<tr>
<td>851-0229-00L</td>
<td>Using Outdoor Education</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.</td>
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<tr>
<td>Abstract</td>
<td>In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.</td>
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</tbody>
</table>
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird

Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

ECTS
H. Stocker
Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Mentored Work Subject Didactics Biology I •

<table>
<thead>
<tr>
<th>Number</th>
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<td>2 credits</td>
<td>4A</td>
<td>P. Faller, H. Stocker</td>
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<td>The Subject Didactics as well as possible branch-specific requirements must be fulfilled prior to commencing the mentored paper.</td>
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<tr>
<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>The objectives for the students are</td>
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<tr>
<td></td>
<td>- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics, pedagogical, and potentially social perspective.</td>
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<td>- to prove that they can independently compile a tuition sequence and develop it to deployment.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Thematische Schwerpunkte</td>
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<tr>
<td></td>
<td>Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.</td>
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<td>Lernformen</td>
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<td></td>
<td>Lecture notes</td>
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<td>Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.</td>
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<td></td>
<td>Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.</td>
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<td>Prerequisites / notice</td>
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<tr>
<td></td>
<td>Beginn nach Absprache jederzeit möglich, jedoch erst nach Abschluss der Fachdidaktik I und II und nach Erfüllung allfälliger fachwissenschaftlicher Auflagen.</td>
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<td></td>
<td>Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.</td>
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Subject Didactics Biology I •

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<tr>
<td>551-0962-00L</td>
<td>Mentored Work Subject Didactics Biology B</td>
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<td>2 credits</td>
<td>4A</td>
<td>P. Faller, H. Stocker</td>
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<td>The Subject Didactics as well as possible branch-specific requirements must be fulfilled prior to commencing the mentored paper.</td>
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<td></td>
<td>The objectives for the students are</td>
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<tr>
<td></td>
<td>Content</td>
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<td>Thematische Schwerpunkte</td>
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<td>Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.</td>
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<td>Lernformen</td>
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<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.</td>
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<td></td>
<td>Literature</td>
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<td></td>
<td>Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Beginn nach Absprache jederzeit möglich, jedoch erst nach Abschluss der Fachdidaktik I und II und nach Erfüllung allfälliger fachwissenschaftlicher Auflagen.</td>
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<td></td>
<td>Die Arbeit sollte vor Beginn des Unterrichtspraktikums abgeschlossen werden.</td>
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Subject Didactics Biology I •

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<tr>
<td>551-0971-00L</td>
<td>Subject Didactics Biology I</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>P. Faller</td>
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<tr>
<td></td>
<td>Simultaneous enrolment in Introductory Internship Biology</td>
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<td>- course 551-0968-00L - is compulsory.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Basic conditions for tuition (MAR - recognition of Matura certificates - curricula, standards), selection of topics and reduction of the complexity of topics.</td>
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<td></td>
<td>- Application of teaching methods and techniques from educational science in biology classes.</td>
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<td></td>
<td>- Planning and preparation of lessons.</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Students can discuss and put into practice in their teaching work the conditions and objectives set out in the regulations governing the school-leaving examination (Matura), the framework curriculum and the conditions and objectives specified by their school.</td>
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<td>- They are in a position to select learning objectives and formulate these on the basis of the target level model. They can plan and prepare lessons and can also develop appropriate learning assignments.</td>
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<tr>
<td></td>
<td>- Students can reconstruct specialist contents in didactic terms and develop teaching modules suitable for the different levels from these on the basis of the subject structure and learner requirements.</td>
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<td></td>
<td>- They can reduce the complexity of subject-based specialist contents and present them in such a way that they are comprehensible and meaningful for learners.</td>
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<td></td>
<td>- They can select appropriate media for their work (e.g. school books) and use these. They can employ appropriate experiments.</td>
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<tr>
<td></td>
<td>- The students can use different forms of examination for monitoring performance.</td>
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<td></td>
<td>- Students are in a position to implement and discuss the concepts of biology teaching and learning on the basis of specific topics covered in school biology.</td>
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</tbody>
</table>
### Professional Training

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0968-00L</td>
<td>Introductory Internship Biology</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>P. Faller</td>
</tr>
<tr>
<td></td>
<td><em>Simultaneous enrolment in Biology Didactics I - course</em> 551-0971-00L - is compulsory.</td>
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</tbody>
</table>

**Abstract**
- During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

**Objective**
- Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

**Content**
- Den Studierenden bietet das Einführungspraktikum einen Einblick in den Berufsalltag einer Lehrperson.

**Literature**
- Wird von der Praktikumsklehrperson bestimmt.

<table>
<thead>
<tr>
<th>Number</th>
<th>Teaching Internship Biology</th>
<th>O</th>
<th>8</th>
<th>17P</th>
<th>P. Faller</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0966-00L</td>
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</table>

**Abstract**
- The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

**Objective**
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

**Literature**
- Wird von der Praktikumsklehrperson bestimmt.

**Prerequisites / notice**
- Findet in der Regel am Schluss der Ausbildung, vor Ablegung der Prüfungslektionen statt.

<table>
<thead>
<tr>
<th>Number</th>
<th>Examination Lesson I Biology</th>
<th>O</th>
<th>1</th>
<th>2P</th>
<th>P. Faller</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0969-01L</td>
<td></td>
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</tbody>
</table>

**Abstract**
- In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**
- On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle.
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**

**Lecture notes / Prerequisites / notice**

<table>
<thead>
<tr>
<th>Number</th>
<th>Examination Lesson II Biology</th>
<th>O</th>
<th>1</th>
<th>2P</th>
<th>P. Faller</th>
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<tbody>
<tr>
<td>551-0969-02L</td>
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</tbody>
</table>

**Abstract**
- In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**
- On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle.
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Die gehaltene Lektion wird kriteriumentbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Nach Abschluss der übrigen Ausbildung.

### Professional Exercises in Biology I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0973-00L</td>
<td>Specialized Biology Course with an Educational Focus: Evolution</td>
<td>O</td>
<td>6 credits</td>
<td>2G+13A</td>
<td>H. Stocker, Y. Barral, K. Köhler</td>
</tr>
</tbody>
</table>

- Students conduct a series of "classical" biological school experiments and therefore gain practice and experience in this area.
- Implementation of Subject Didactics I and II with the focus on conducting biological experiments in schools. This includes finding, testing and further developing suitable protocols for different subject areas of school biology. Working out how to didactically embed the experiments in lessons.
- Students can perform, off the cuff, 12 school experiments (which they have tested themselves), from the different subject areas, and conduct these correctly in technical terms. They can incorporate these experiments in their tuition in a didactically meaningful manner.
- By contrast to the Subject Specialisation 1 and 2 course units, these are "basic tests" and do not involve the implementation of current research topics. The students' compilations are available in a data archive.

2. Die Studierenden führen alle ausgearbeiteten Experimente selber durch.

Hand out of course material.


#### Compulsory Elective Courses

- see Compulsory Elective Courses Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0180-00L</td>
<td>Research Ethics ●</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>G. Achermann, P. Emch</td>
</tr>
</tbody>
</table>

- Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Participants of the course Research Ethics will
- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people's arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;

- Number of participants limited to 40
- Particularly suitable for students of D-BIOL, D-CHAB, D-HEST

I. Introduction to Moral Reasoning

1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in Research Ethics

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk/benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!);
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories assessed
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Domain B - Method-specific Competencies
- Communication assessed
- Cooperation and Teamwork assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed

Domain C - Social Competencies

Domain D - Personal Competencies

701-0015-00L Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement
W 2 credits 2S M. Stauffacher, C. E. Pohl, B. Vienni Baptista

All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture.
The lecture takes place if a minimum of 12 students register for it.

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.
The seminar covers the following topics:

1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

The seminar covers the following topics:

1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
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2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.
This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units

2. Reading assignments, available via Moodle, for a few selected course units

3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Lecture notes
Assigned reading materials and slides will be available via Moodle.

Literature
Assigned reading materials and slides will be available via Moodle.

Prerequisites / notice
This course will take place fully online. Course units have three components:

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To facilitate your planning, the course is organized in terms of weekly units.
Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
Basic knowledge of the anatomy and physiology of tissues, of the embryonal and postnatal development, the sensory organs, the neuromuscular system, the cardiovascular system and the respiratory system.

Objective
Basic knowledge of human anatomy and physiology basics of clinical pathophysiology.

Content

Anatomy and Physiology I (fall term):
Basics of cytology, histology, embryology; nervous system, sensory organs, muscles, cardiovascular system, respiratory system

Anatomy and Physiology II (spring term):
digestive tract, endocrine organs, metabolism and thermoregulation, skin, blood and immune system, urinary system, circadian rhythm, reproductive organs, pregnancy and birth.

Prerequisites / notice
Requirements: 1st year, scientific part.
Part of the course is read and checked in English.

752-4001-00L Microbiology | E- | 2 credits | 2V | M. Ackermann, M. Schuppler, J. Vorholt-Zambelli |

Abstract
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective
Teaching of basic knowledge in microbiology.

Content

Lecture notes
Wird von den jeweiligen Dozenten ausgegeben.

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

551-0127-01L Plants and Fungi | E- | 4 credits | 3G | S. C. Zeeman, M. Künzler, O. Y. Martin |

Abstract
The lecture conveys the fundamental concepts underlying multicellularity with an emphasis on the molecular basis of multicellular biological systems and their functional integration into coherent wholes. The structural and functional specialization in multicellular organisms will be discussed by highlighting common and specific functions in fungi and plants.

Objective
1. Students can describe advantages and challenges associated with being multicellular and outline independent solutions that organisms have developed to cope with the challenges of complex multicellularity
2. Students can explain how the internal and external structures of fungi and plants function to support survival, growth, behavior, and reproduction.
3. Students can explain the basic pathways and mechanisms of cellular communication regulating cellular behavior (cell adhesion, metabolism, proliferation, reproduction, development).
4. Students can describe how a single cell develops from one cell into many, each with different specialized functions.

Content
The lecture introduces the structural and functional specialization in fungi and plants. After providing an overview on the diversity of eukaryotic organisms, the lecture will discuss how fungi and plants have evolved structures and strategies to cope with the challenges of multicellularity. The molecular basis underlying communication, coordination and differentiation will be conveyed and complemented by key aspects of reproduction, metabolism development, and regeneration. Topics include form and function of fungi and plants, metabolism, cell signaling, adhesion, stem cells, regeneration, reproduction, and development.

Literature
Campbell “Biology”, 11th Edition

Prerequisites / notice
Some lecture are held in English.

Biology Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
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</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td></td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>P</td>
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<tr>
<td>U</td>
<td>exercise</td>
<td>A</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-2413-00L</td>
<td><strong>Evolutionary Genetics</strong></td>
<td>O</td>
<td>6</td>
<td>4V</td>
<td>T. Städler, A. Widmer, S. Fior, M. C. Fischer, J. Stapley</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
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<td>The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory. Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem. Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Handouts</td>
</tr>
<tr>
<td>701-0328-00L</td>
<td><strong>Advanced Ecological Processes</strong></td>
<td>O</td>
<td>4</td>
<td>2V</td>
<td>J. Hille Ris Lambers</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>This course presents the theoretical and empirical approaches used to understand the ecological processes structuring communities. Central problems in community ecology including the dynamics of species interactions, the influence of spatial structure, the controls over species invasions, and community responses to environmental change will be explored from basic and applied perspectives.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
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<td></td>
<td>Students will understand how ecological processes operate in natural communities. They will appreciate how mathematical theory, field experimentation, and observational studies combine to generate a predictive science of ecological processes, and how this predictive science informs conservation and management decisions.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Upon completing the course, students will be able to: Understand the factors determining the outcome of species interactions in communities, and how this information informs management. Apply theoretical knowledge on species interactions to predict the potential outcomes of novel species introductions. Understanding the role of spatial structure in mediating population dynamics and persistence, species interactions, and patterns of species diversity. Use population and community models to predict the stability of interactions between predators and prey and between different competitors. Understand the conceptual basis of predictions concerning how ecological communities will respond to climate change. Discuss the types of conceptual advances ecology as a science can realistically achieve, and how these relate to the applications of the discipline.</td>
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<tr>
<td></td>
<td>Taught competencies</td>
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<tr>
<td></td>
<td>Domain A - Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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For students of the following study programmes only: Biology Master Teaching certificate Biology Environmental Sciences Master UZH MNF Biology UZH MNF Geography /Earth Sciences
Elective Compulsory Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-4801-00L</td>
<td>System-Oriented Management of Herbivore Insects</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>to be announced</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td>Abstract</td>
<td>The focus is on the potential to assess strategies and tactics of pest management, in view of the demands from the economy, environment and society. Significant management measures will be explained using practical examples, such as surveillance and forecasting, resistance management, biological control as well as the use of plant protection products, incl. regulatory aspects and ecotoxicology.</td>
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<tr>
<td>Objective</td>
<td>The students gain a good understanding of fundamental aspects of pest management in agroecosystems. They will be able to assess options for action in view of requirements from the economy, environment and society. Further, they will learn to elaborate on current issues in pest management, and to critically evaluate case studies.</td>
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| 701-1409-00L | Research Seminar: Ecological Genetics | W    | 2 credits | 1S    | S. Flor                 |
|              | Minimum number of participants is 5.     |      |      |       |                         |
| Abstract     | In this research seminar we will critically discuss recent publications on current topics in Ecological Genetics. |      |      |       |                         |
| Objective    | It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess and appreciate scientific publications in this field. |      |      |       |                         |
| Lecture notes | Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course. It is strongly recommended that participants have in advance successfully participated in the course Evolutionary Genetics (701-2413-00) or Ecological Genetics (701-1413-01). |      |      |       |                         |

| 751-5121-00L | Insect Ecology | W    | 2 credits | 2V    | C. De Moraes, M. Mescher, N. Stanczyk |
|              | The number of participants is limited to 30. |      |      |       |                         |
| Abstract     | This is an introductory class on insect ecology. During the course you will learn about insect interactions with, and adaptations to, their environment and other organisms, and the importance of insect roles in our ecosystems. This course includes lectures, small group discussions and outside readings. |      |      |       |                         |
| Objective    | The aim of the course is to gain an understanding of how insects have specialised and adapted to occupy diverse environmental niches and become vital to ecosystem processes. Important topics include: insect-plant interactions, chemical ecology, predator-prey interactions, vectors of disease, social insects, mutual and parasitic interactions and examining insect ecology in an evolutionary context. |      |      |       |                         |
| Lecture notes | Provided to students through Moodle. Selected required readings (peer reviewed literature). Optional recommended readings with additional information. |      |      |       |                         |

| 401-0625-01L | Applied Analysis of Variance and Experimental Design | W    | 5 credits | 2V+1U | L. Meier |
| Abstract     | Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power. |      |      |       |                         |
| Objective    | Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R. |      |      |       |                         |
| Content      | Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power. |      |      |       |                         |
| Prerequisites / notice | The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held. |      |      |       |                         |

| 401-0649-00L | Applied Statistical Regression | W    | 5 credits | 2V+1U | M. Dettling |
| Abstract     | This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis. |      |      |       |                         |
| Objective    | The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling. The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data. |      |      |       |                         |
| Content      | The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies. |      |      |       |                         |
| Lecture notes | A script will be available. |      |      |       |                         |
| Literature   | Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis |      |      |       |                         |
| Prerequisites / notice | The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held. |      |      |       |                         |

At the end of the course...

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

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management not assessed

Domain C - Social Competencies
- Communication assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed

701-0301-00L Applied Systems Ecology

Objective
At the end of the course...
- you know how to structure your inquiry and how to proceed the analysis when faced with a complex environmental issue. You can formulate the relevant questions, find answers (supported by discussions, input from the lecturers and the literature), and you are able to present your conclusions clearly and cautiously.
- you understand the complexity of interactions and structures in ecosystems. You know how ecosystem processes, functions and services interact and feed back across multiple spatio-temporal scales (in general, plus in depth case examples).
- you understand that biodiversity and the interaction between organisms are an integral part of ecosystems. You are aware that the link between biodiversity and process/function/service is rarely fully understood. You know how to honestly deal with this lack of understanding and can nevertheless find, critically analyse and communicate solutions.
- you understand the importance of ecosystem services for society.
- you have an overview of the methods of ecosystem research and have a deeper insight into some of them, e.g. ecosystem observation, manipulation and modelling.
- you have reflected on ecology as a young discipline at the heart of significant applied questions.

Content
This course provides the ecological systems' knowledge needed to question applied sustainability solutions. We will critically assess the complexity of current environmental issues, illustrating basic ecological concepts and principles. Our central aim is to balance participants' respect for complexity with a sense of possibility by providing examples from the vast solution space offered by ecological systems, such as e.g. green infrastructure to manage water.

The course is structured around four larger topical areas: (1) Integrated Water Management -- Green infrastructure (land management options) as an alternative to engineered solutions (e.g. large reservoirs) in flood and drought management; (2) Fire dynamics, the water cycle and biodiversity -- The surprising dynamics of species life cycles and populations in arid landscapes; (3) Rewilding, e.g. re-introducing apex predators (e.g. wolves), or large ungulates (e.g. bisons) in protected areas -- A nature conservation trend with counterintuitive effects; (4) Coupling of aquatic and terrestrial systems: carbon, nitrogen and phosphorus transfers of global importance on landscape scale.

Lecture notes
Case descriptions, commented glossary and a list of literature and further resources per case.

Prerequisites / notice
Schulze et al. (2005) Plant Ecology; Springer.


401-6215-00L Using R for Data Analysis and Graphics (Part I)
The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

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

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

Lecture notes
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

Prerequisites / notice
The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should “automatically” make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=15518

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401-6217-00L Using R for Data Analysis and Graphics (Part II) W 1.5 credits 1G M. Mächler

Abstract
The course provides the second part an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions.

Note: This part builds on “Using R... (Part I)”, but can be taken independently if the basics of R are already known.

Objective
The students will be able to use the software R efficiently for data analysis, graphics and simple programming.

Content
The course provides the second part of an introduction to the statistical software R (https://www.r-project.org/) for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part II of the course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options
- Extending basic R: packages

Lecture notes

Prerequisites / notice
Basic knowledge of R equivalent to “Using R .. (part 1)” (= 401-6215-00L) is a prerequisite for this course.

The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should “automatically” make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=15522

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751-4504-00L Plant Pathology I W 2 credits 2G B. McDonald

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

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

Lecture Topics and Tentative Schedule

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

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

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

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

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

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

Week 7  

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

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

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

Week 11  

Week 12  

Week 13  
Cultural control methods: fertilizers, crop rotations.

Week 14  
Open lecture.

Lecture notes  
Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

636-0017-00L  
Computational Biology  
W  
6 credits  
3G+2A  
T. Vaughan

Abstract  
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective  
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

Content  
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes  
Lecture slides will be available on moodle.

Literature  
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.
Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course ‘Introduction to Programming’, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date. For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lemeinheit.view?semkez=2018W&amp;ansicht=KATALOGDATEN&amp;lemeinheitid=123546&amp;lang=d, e, or working through the script provided as part of this R course.

701-1471-00L
Ecological Parasitology

W 3 credits 1V+1P J. Jokela, C. Vorburger

Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.

Objective
1. Identify common macroparasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

Content
Lectures:
1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
2. Adaptations of parasites (e.g. evolution of life-cycles, host manipulation).
3. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
4. Ecology and evolution of parasitoids and their applications in biocontrol
5. Human macroparasites (schistosomiasis, malaria).

Practical exercises:
1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).
2. Examination of parasites in amphipods (identification and examination of effects on hosts).
3. Examination of parasitoids of aphids.

Waiting list will be deleted on October 1st, 2021.

701-1427-00L
Experimental Evolution

W 4 credits 2S G. Velicer, A. Hall

Does not take place this semester. Semester change.

This lecture will be offered in Spring Semester 2022 for the next time.

Abstract
Students will analyze experimental evolution literature covering a wide range of questions, species and types of analysis and will lead discussions of this literature. Students will develop a written project proposal for a novel evolution experiment (or a novel analysis of a published experiment) to address an unanswered question and will also deliver an oral presentation of the project proposal.

Objective
Course objectives:
1) become familiar with a diverse sample of experimental evolution literature,
2) gain understanding of the strengths and limitations of experimental evolution for addressing evolutionary questions relative to other forms of evolutionary analysis, and
3) gain the ability to effectively design and analyze evolution experiments that address fundamental or applied questions in evolutionary biology.

Content
Experimental evolution is a powerful and increasingly prominent approach to investigating evolutionary processes. Students will analyze experimental evolution literature covering a diverse range of topics, species and types of analysis and will lead discussions of this literature. Students will develop a written project proposal for a novel evolution experiment (or a novel analysis of a published experiment) to address an unanswered question and will also deliver an oral presentation of the project proposal. Evaluation will be based on a combination of participation in and leadership of literature discussions, in-class exams, and oral and written presentations of the project proposal.

Literature
Primary research papers and review articles.

Prerequisites / notice
701-0245-00 Evolutionary Analysis (or equivalent).

701-1703-00L
Evolutionary Medicine for Infectious Diseases

W 3 credits 2G A. Hall

Number of participants limited to 35.

Waiting list will be deleted October 3rd, 2021.

Abstract
This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective
Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content
We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (~ 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature
The focus is on primary literature, but for some parts the following text books provide good background information:

Schmid Hempel 2011 Evolutionary Parasitology
Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

636-0009-00L
Evolutionary Dynamics

W 6 credits 2V+1U+2A N. Beerenswinkel

Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.
Objective

The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

Content

Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.

Lecture notes

No.

Literature


Prerequisites / notice

Prerequisites: Basic mathematics (linear algebra, calculus, probability)

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories (assessed)

Domain B - Method-specific Competencies
- Analytical Competencies (assessed)
- Problem-solving (assessed)

Domain C - Social Competencies
- Communication (not assessed)
- Cooperation and Teamwork (not assessed)

Domain D - Personal Competencies
- Critical Thinking (assessed)
- Self-direction and Self-management (not assessed)

Elective Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>W. D. Hardt, L. Eberl, J. Piel, M. Pilhofer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<tr>
<td>Objective</td>
<td>This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<tr>
<td>Content</td>
<td>Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Updated handouts will be provided during the class.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>English</td>
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<td>Taught competencies</td>
<td>The lecture &quot;Grundlagen der Biologie II: Mikrobiologie&quot; is the basis for this advanced lecture.</td>
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| 551-0309-00L | Concepts in Modern Genetics               | W    | 6    | 4V    | Y. Barral, D. Bopp, A. Hajnal, O. Voinnet |
| Abstract    | Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH. |
| Objective   | Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html |
| Content     | Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference. |
| Lecture notes | Scripts and additional material will be provided during the semester. |

| Abstract    | This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include: genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming. |
| Objective   | The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference. |
| Lecture notes | The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data. |
Content

Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation
Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice
Course participants have already acquired basic programming skills in Python and R.
Students will bring and work on their own laptop computers, preferentially running the latest versions of Windows or MacOSX.

Elective Major: Microbiology and Immunology

Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>W.-D. Hardt, L. Eberl, J. Piel, M. Pilhofer</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td>This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td>Lecture notes</td>
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<td>Updated handouts will be provided during the class.</td>
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<td>Literature</td>
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<td>Current literature references will be provided during the lectures.</td>
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<td>Prerequisites / notice</td>
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| 551-0317-00L| Immunology I             | O    | 3    | 2V    | M. Kopf, A. Oxenius      |
|             | Abstract                |      |      |       |                           |
|             | Introduction into structural and functional aspects of the immune system. |
|             | Basic knowledge of the mechanisms and the regulation of an immune response. |
|             | Objective               |      |      |       |                           |
|             | Introduction into structural and functional aspects of the immune system. |
|             | Basic knowledge of the mechanisms and the regulation of an immune response. |
|             | Content                 |      |      |       |                           |
|             | - Introduction and historical background |
|             | - Innate and adaptive immunity, Cells and organs of the immune system |
|             | - B cells and antibodies |
|             | - Generation of diversity |
|             | - Antigen presentation and Major Histoincompatibility (MHC) antigens |
|             | - Thymus and T cell selection |
|             | - Autoimmunity |
|             | - Cytotoxic T cells and NK cells |
|             | - Th1 and Th2 cells, regulatory T cells |
|             | - Allergies |
|             | - Hypersensitivities |
|             | - Vaccines, immune-therapeutic interventions |
|             | Lecture notes           |      |      |       |                           |
|             | Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien" |
|             | Literature              |      |      |       |                           |
|             | - Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020 |
|             | Prerequisites / notice  |      |      |       |                           |
|             | For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session. |

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies not assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking not assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed
This course provides a detailed understanding of - development of T and B cells - the dynamics of an immune response during acute and chronic infection - mechanisms of immunopathology - modern vaccination strategies

Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

- Immunology III
- Current Topics in Molecular and Cellular Neurobiology
- Cutting Edge Topics: Immunology and Infection Biology

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html/
Domain A - Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

Domain C - Social Competencies

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

Domain D - Personal Competencies

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

551-1153-00L
Systems Biology of Metabolism

W 4 credits 2V

U. Sauer, N. Zamboni, M. Zampieri

Number of participants limited to 15.

Abstract
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

Objective
Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

Content
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

Lecture notes
Script and original publications will be supplied during the course.

Prerequisites / notice
The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

551-1171-00L
Immunology: From Milestones to Current Topics

W 4 credits 2S

B. Ludewig, J. Kisielow, A. Oxenius, L. Tortola, University lecturers

Number of participants limited to 20.

Abstract
Milestones in Immunology: on old concepts and modern experiments

Objective
The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, myeloid cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.

Content
Milestones and current topics of innate immunity, antigen presentatino, B cells, thymus and T cells, cytotoxic T cells, NK cells, stromal cells, CNS immunity and tumor immunology.

Lecture notes
Original and review articles will be distributed by the respective lecturer.

Literature
Literaturunterlagen werden vor Beginn des Kurses auf folgender website zugänglich sein: https://moodle-app2.let.ethz.ch/course/view.php?id=15568

551-1303-00L
Cellular Biochemistry of Health and Disease

W 4 credits 2S

V. Korkhov, T. Ishikawa, M. Jagannathan, R. Kroschewski, G. Neurohr, M. Peter, A. E. Smith, B. Snijder, K. Weis

Number of participants limited to 20.

Abstract
During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. Students will participate in discussion of the primary paper, including the foundation of the biological question, specific questions addressed, key methods, key results, remaining gaps and research implications.

Objective
Students will alternate as discussion leaders throughout the semester, with the student leader responsible to briefly summarize key general knowledge and context of the assigned primary research paper. Together with the faculty expert, all students will participate in discussion of the primary paper, including the foundation of the biological question, specific questions addressed, key methods, key results, remaining gaps and research implications.

Content
Original and review articles will be distributed by the respective lecturer.

Literature
The literature will be provided during the course

Prerequisites / notice
The course will be taught in English.

752-4009-00L
Molecular Biology of Foodborne Pathogens

W 3 credits 2V

M. Loessner, M. Schmelcher, M. Schupppler, E. Wetter Slack

Abstract
The course includes hands-on classroom work and lab exercises that cover the molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.
Objective

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature

Recommendations will be given in the first lecture

Prerequisites / notice

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break !
Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

Lecture Topics and Tentative Schedule

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

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

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

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

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

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


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

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

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


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

Week 13  Cultural control methods: fertilizers, crop rotations.

Week 14  Open lecture.

Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics
- epidemiology
- pathogen evolution
- macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course ‘Introduction to Programming’, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.cbb.ethez.ch/news-events.html
For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethez.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d, or working through the script provided as part of this R course.

701-1703-00L Evolutionary Genetics W 6 credits 4V T. Städler, A. Widmer, S. Fior, M. C. Fischer, J. Stapley

Number of participants limited to 35.

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Abstract
The concept course ‘Evolutionary Genetics’ consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Content
The focus is on primary literature, but for some parts the following text books provide good background information:

- M. Loessner
- T. Städler

Number
752-4005-00L Food Microbiology I W 3 credits 2G M. Loessner

Abstract
This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective
Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content
We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Waiting list will be deleted October 3rd, 2021.

M. C. Fischer, J. Stapley

Autumn Semester 2021

Page 287 of 2152
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

The course "Molecular Life of Plants" will cover the following topics:

- Plant genome organization and evolution
- Plant functional genomics and systems biology
- Plant genome engineering and editing
- Seed development and embryogenesis
- Root apical meristem: structure, function and hormone regulation
- Shoot apical meristem: structure, function and hormone regulation
- Mobilization of seed reserves
- Heterotrophic to autotrophic growth
- Chloroplast biogenesis and light perception
- Photosynthetic and central carbon metabolism
- Integration of carbon and nitrogen metabolism
- Principles of RNA silencing
- MicroRNAs: discovery and modes of action
- RNA silencing and pathogen defense
- RNA silencing movement, amplification and trans-generational silencing
- Plants and the environment
- Plant-pathogen interactions: pathogen attack, first layers of plant defense and plant responses
- Senescence

**551-0311-00L Molecular Life of Plants**  
**Objective**

The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

**551-0307-00L Molecular and Structural Biology I: Protein Structure and Function**

- D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course

**Objective**

Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

**551-0309-00L Concepts in Modern Genetics**

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

**Objective**

This course focuses on the concepts of classical and modern genetics and genomics.

**551-0319-00L Cellular Biochemistry (Part I)**

**Content**

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**

Scripts and additional material will be provided during the semester.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Information for UZH students: Please enrol at ETH for this module: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

**Lecture notes Literature**

- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.
- Current topics: References will be given during the lectures.

**Literature**

Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

529-0731-00L  Nucleic Acids and Carbohydrates

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<tr>
<td>D. Hilvert, P. A. Kast, S. J. Sturla, H. Wennemers</td>
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Abstract

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Objective

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes

No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature

Mainly based on original literature, a detailed list will be distributed during the lecture.

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies

Problem-solving

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Domain D - Personal Competencies

Self-awareness and Self-reflection

Self-direction and Self-management

551-1299-00L  Introduction to Bioinformatics

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<th>6 credits</th>
<th>4G</th>
</tr>
</thead>
</table>

Abstract

This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include: genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming.

Objective

The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data.

Content

Ethics:

Case studies to learn about applying ethical principles in human genomics research

Genomics:

Genetic variant calling

Analysis and critical evaluation of genome wide association studies

Metagenomics:

Reconstruction of microbial genomes

Microbial community compositional analysis

Quantitative metagenomics

Network bioinformatics:

Inference of molecular networks

Use of networks for interpretation of (gen)omics data

Imaging:

High throughput single cell imaging

Image segmentation

Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice

Course participants have already acquired basic programming skills in Python and R.

Students will bring and work on their own laptop computers, preferably running the latest versions of Windows or MacOSX.
Students will be guided to choose their papers based on recent literature published less than 1 year prior in a relevant journal.

D. Bopp, A. Hajnal, Current Topics in Metabolism and Disease

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and metabolism of diseases. The course introduces the students to recent developments in the fields of metabolism and disease. It also supports the development of analytical skills, including critical reading of scientific literature, being able to present and critically discuss scientific experiments, point out technical limitations, and placing recent discoveries in the broader context of biology, physiology and medicine. The student should be able to grasp what the authors wanted to learn i.e. their hypothesis and their goals, why the authors chose the experimental approach and methods used, the strengths and weaknesses of the experiments, the quality of the data presented, the conclusions drawn, and how the work fits into the wider literature in the field. Furthermore, the student should discuss alternative approaches and future experiments. Each student will present one paper during the course, which provides him/her with practice in public speaking.

Presentations will be made available after the seminars.

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular processes. In addition, the students will be able to describe the spatial and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Each student will present at least once during the semester. The presentation includes an introduction to the field of the paper, a critical description of the main results, a summary of the main points and a discussion of their significance. Every participant is expected to take part in the discussion and to ask questions. At each meeting, all students are expected to read and prepare the paper beforehand. Each paper presented will be announced one week in advance of the presentation.

Lecture notes

Presentations will be made available after the seminars.

Literature

Students will be guided to choose their papers based on recent literature published less than 1 year prior in a relevant journal.

Elective Master Courses

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

Elective Major: Cell Biology

Elective Compulsory Concept Courses

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
551-0319-00L | Cellular Biochemistry (Part I) | W | 3 credits | 2V | U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp

Abstract

Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective

The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular processes. In addition, the students will be able to describe the spatial and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Lecture notes

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature

Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice

To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

551-0309-00L | Concepts in Modern Genetics | W | 6 credits | 4V | Y. Barral, D. Bopp, A. Hajnal, O. Vainnet

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/2018/summer/degree.html

Abstract

Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective

This course focuses on the concepts of classical and modern genetics and genomics.

Content

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes

Scripts and additional material will be provided during the semester.

551-0317-00L | Immunology I | W | 3 credits | 2V | M. Kopf, A. O xenius

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective

Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.
**Content**

- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

**Lecture notes**

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

**Prerequisites / notice**

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

**Taught competencies**

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

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**551-1299-00L Introduction to Bioinformatics**

**W 6 credits 4G**


**Abstract**

This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include: genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming.

**Objective**

The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data.

**Content**

**Ethics:**

- Case studies to learn about applying ethical principles in human genomics research

**Genomics:**

- Genetic variant calling
- Analysis and critical evaluation of genome wide association studies

**Metagenomics:**

- Reconstruction of microbial genomes
- Microbial community compositional analysis
- Quantitative metagenomics

**Network bioinformatics:**

- Inference of molecular networks
- Use of networks for interpretation of (gen)omics data

**Imaging:**

- High throughput single cell imaging
- Image segmentation
- Automatic analysis of drug effects on single cell suspension (chemotyping)

**Prerequisites / notice**

Course participants have already acquired basic programming skills in Python and R.

Students will bring and work on their own laptop computers, preferentially running the latest versions of Windows or MacOSX.

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**Elective Compulsory Master Courses**

**Number**

<table>
<thead>
<tr>
<th>551-0512-00L</th>
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</table>

**Title**

- Current Topics in Molecular and Cellular Neurobiology

**Type**

- W

**ECTS**

- 2

**Hours**

- 1S

**Lecturers**

- U. Suter

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

Content
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.
You are expected to take part in the discussion and to ask questions. To prepare for this you should read all the papers beforehand (they will be announced a week in advance of the presentation).

Lecture notes
Presentations will be made available after the seminars.

Prerequisites / notice
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

---

**551-0571-00L**  
*From DNA to Diversity (University of Zurich)*

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.*

**UZH Module Code:** BIO336

*Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html*

**Abstract**
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.

**Objective**
By the end of this module, each student should be able to
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

**Key skills:**
- By the end of this module, each student should be able to
- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

**Lecture notes**
Presentations will be made available after the seminars.

**Prerequisites / notice**
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

**551-1117-00L**  
*Cutting Edge Topics: Immunology and Infection Biology*

*Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIO636 at UZH.*

*Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-special-students-university-of-zurich.html*

**Abstract**
Weekly seminar about cutting edge topics in immunology and infection biology. Internationally renowned experts present their current research followed by an open discussion.

**Objective**
Weekly seminar about cutting edge topics in immunology and infection biology. Internationally renowned experts present their current research followed by an open discussion.
The aim of this course is to confront students with current research topics and with scientific presentation. The course offers the opportunity to gain in depth knowledge about diverse topics which are often only briefly touched in the concept courses and to engage in discussion with experts in the field.

**Content**
Immunology and infection biology.
The specific topics are variable and depend each semester on the list of invited experts.

**Lecture notes**
Current research data (often not yet published) are presented in this seminar series. There is no script and we are not allowed to record or distribute the contents of the seminars. Thus, the ability of students to extract the most relevant points of each seminar is promoted, which is an important skill for the future attendance of scientific meetings.

**Literature**
Often parts of the presented seminars have already been published by the respective speakers and the respective primary research can be retrieved from scientific journals.

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During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<th>Domain B - Method-specific Competencies</th>
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<tbody>
<tr>
<td>Analytical Competencies</td>
<td>not assessed</td>
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<tr>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<tr>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Project Management</td>
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<th>Domain C - Social Competencies</th>
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<tbody>
<tr>
<td>Communication</td>
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<tr>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<th>Domain D - Personal Competencies</th>
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<tbody>
<tr>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<tr>
<td>Self-direction and Self-management</td>
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### Systems Biology of Metabolism

<table>
<thead>
<tr>
<th>551-1153-00L</th>
<th>Systems Biology of Metabolism</th>
<th>W 4 credits 2V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various approaches, metabolic flux analyses, metabolomics and other omics.</td>
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<tr>
<td>Lecture notes</td>
<td>Script and original publications will be supplied during the course.</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.</td>
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</tbody>
</table>

### Immunology: From Milestones to Current Topics

<table>
<thead>
<tr>
<th>551-1171-00L</th>
<th>Immunology: From Milestones to Current Topics</th>
<th>W 4 credits 2S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, myeloid cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.</td>
<td></td>
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<tr>
<td>Content</td>
<td>Milestones and current topics of innate immunity, antigen presentatio, B cells, thymus and T cells, cytotoxic T cells, NK cells, stromal cells, CNS immunity and tumor immunology.</td>
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<tr>
<td>Lecture notes</td>
<td>Original and review articles will be distributed by the respective lecturer.</td>
<td></td>
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<td>Adaptability and Flexibility</td>
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<td>Self-awareness and Self-reflection</td>
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### Cellular Biochemistry of Health and Disease

<table>
<thead>
<tr>
<th>551-1303-00L</th>
<th>Cellular Biochemistry of Health and Disease</th>
<th>W 4 credits 2S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to introduce, present, evaluate, critically discuss and write about recent scientific articles in the research area of cellular biochemistry.</td>
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<tr>
<td>Literature</td>
<td>The literature will be provided during the course</td>
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### Enzymes

<table>
<thead>
<tr>
<th>529-0733-01L</th>
<th>Enzymes</th>
<th>W 6 credits 3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Overview of enzymes, enzyme-catalyzed reactions and metabolic processes.</td>
<td></td>
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</tbody>
</table>

### Prerequisites / notice

- Number of participants limited to 15.
- Milestones in Immunology: on old concepts and modern experiments
- Number of participants limited to 20.
- The literature will be provided during the course
- The course will be taught in English.
### 551-1407-00L RNA Biology Lecture Series I: Transcription & Processing & Translation

<table>
<thead>
<tr>
<th>Content</th>
<th>A script will not be handed out.</th>
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</thead>
<tbody>
<tr>
<td>Literature</td>
<td>In addition, citations from the literature relevant to the individual lectures will be assigned weekly.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>551-1407-00L</th>
<th>RNA Biology Lecture Series I: Transcription &amp; Processing &amp; Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.</td>
</tr>
<tr>
<td>Objective</td>
<td>The students should obtain an understanding of these processes, which are at work during gene expression.</td>
</tr>
<tr>
<td>Content</td>
<td>Transcription &amp; 3'end formation; splicing, alternative splicing, RNA editing; the ribosome &amp; translation, translation regulation, RNP biogenesis &amp; nuclear export, miRNA surveillance &amp; miRNA turnover; signal transduction &amp; RNA.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Basic knowledge of cell and molecular biology.</td>
</tr>
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<thead>
<tr>
<th>551-1407-00L</th>
<th>RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics</th>
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</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.</td>
</tr>
<tr>
<td>Objective</td>
<td>The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.</td>
</tr>
<tr>
<td>Content</td>
<td>Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Basic knowledge of cell and molecular biology.</td>
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<tr>
<th>551-0223-00L</th>
<th>Immunology III</th>
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<tbody>
<tr>
<td>Abstract</td>
<td>This course provides a detailed understanding of - development of T and B cells - the dynamics of an immune response during acute and chronic infection - mechanisms of immunopathology - modern vaccination strategies Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.</td>
</tr>
<tr>
<td>Objective</td>
<td>Obtain a detailed understanding of - the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses, - Recognition of pathogenic microorganisms by the host cells and molecular events thereafter, - events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells, - Optimization of B cell responses by intelligent design of new vaccines - Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg) - NK T cells and responses to lipid antigens - Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17 - Overview of cytokines and their effector function - Co-stimulation (signals 1-3) - Dendritic cells - Evolution of the &quot;Danger&quot; concept - Cells expressing Pattern Recognition Receptors and their downstream signals - T cell function and dysfunction in acute and chronic viral infections</td>
</tr>
<tr>
<td>Content</td>
<td>o Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg) o NK T cells and responses to lipid antigens o Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17 o Overview of cytokines and their effector function o Co-stimulation (signals 1-3) o Dendritic cells o Evolution of the &quot;Danger&quot; concept o Cells expressing Pattern Recognition Receptors and their downstream signals o T cell function and dysfunction in acute and chronic viral infections</td>
</tr>
<tr>
<td>Literature</td>
<td>Documents of the lectures are available for download at: <a href="https://moodle-app2.let.ethz.ch/course/view.php?id=2581&amp;notifyeditingon=1">https://moodle-app2.let.ethz.ch/course/view.php?id=2581&amp;notifyeditingon=1</a></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Immunology I and II recommended but not compulsory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>227-0939-00L</th>
<th>Cell Biophysics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.</td>
</tr>
<tr>
<td>Objective</td>
<td>Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.</td>
</tr>
<tr>
<td>Objective of this course</td>
<td>To show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy. Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.</td>
</tr>
<tr>
<td>By the end of the course</td>
<td>Students will also learn to critically evaluate the concepts of making an assumption and making an approximation.</td>
</tr>
</tbody>
</table>
Content

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Lecture notes

Theory and corresponding exercises are merged together during the classes.

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature


Prerequisites / notice

Notions of vectors in 2D and 3D are beneficial.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

Domain D - Personal Competencies

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

376-1305-01L Neural Systems for Sensory, Motor and Higher Brain Functions

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO343 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract

The course covers the structure, plasticity and regeneration of the adult nervous system (NS) with focus on: sensory systems, cognitive functions, learning and memory, molecular and cellular mechanisms, animal models, and diseases of the NS.

Objective

The aim is to give a deepened insight into the structure, plasticity and regeneration of the nervous system based on molecular, cellular and biochemical approaches.

Content

The main focus is on the structure, plasticity and regeneration of the NS: biology of the adult nervous system; structural plasticity of the adult nervous system, regeneration and repair: networks and nerve fibers, regeneration, pathological loss of cells.

Literature

The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle / OLAT.

376-1305-00L Development of the Nervous System (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: BIO344

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.
Objective
On successful completion of the module the student should be able to
- relate structure and function of the nervous system to its development
- apply principles of molecular, cellular, and developmental biology
to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to
- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular, and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz as BIC0344

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
None. Bring something to write and your student ID

551-1423-00L Concepts in Modern Genetics
W 2 credits 1S to be announced

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Stoffel Lab in the Institute of Molecular Health Sciences, will present a comprehensive presentation of a recent paper published in a top ranking international peer reviewed journal that relates to metabolism and disease.

Objective
The course introduces the students to recent developments in the fields of metabolism and disease. It also supports the development of analytical skills, including critical reading of scientific literature, being able to present and critically discuss scientific experiments, point out technical limitations, and placing recent discoveries in the broader context of biology, physiology, and medicine. The student should be able to grasp what the authors wanted to learn i.e. their hypothesis and their goals, why the authors chose the experimental approach and methods used, the strengths and weaknesses of the experiments, the quality of the data presented, the conclusions drawn, and how the work fits into the wider literature in the field. Furthermore, the student should discuss alternative approaches and future experiments. Each student will present one paper during the course, which provides him/her with practice in public speaking.

Content
Each student will present at least once during the semester. The presentation includes an introduction to the field of the paper, a critical description of the main results, a summary of the main points and a discussion of their significance. Every participant is expected to take part in the discussion and to ask questions. At each meeting, all students are expected to read and prepare the paper beforehand. Each paper presented will be announced one week in advance of the presentation.

Lecture notes
Presentations will be made available after the seminars.

Literature
Students will be guided to choose their papers based on recent literature published less than 1 year prior in a relevant journal.

Elective Major: Molecular Health Sciences

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide
Content

Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation
Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice
Course participants have already acquired basic programming skills in Python and R.

Students will bring and work on their own laptop computers, preferentially running the latest versions of Windows or MacOSX.

➤➤➤ Elective Compulsory Master Courses
See D-BIOL Master Studies Guide

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0571-00L</td>
<td>From DNA to Diversity (University of Zurich)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>A. Hajnal, D. Bopp</td>
</tr>
<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: BIO336</td>
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<td></td>
<td>Mind the enrolment deadlines at UZH:</td>
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</tbody>
</table>

Abstract
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.

Objective
By the end of this module, each student should be able to
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

Key skills:
By the end of this module, each student should be able to
- present and discuss a relevant evolutionary topic in an oral presentation
- select and integrate key concepts in animal evolution from primary literature
- participate in discussions on topics presented by others

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<tr>
<th>Number</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1303-00L</td>
<td>Cellular Biochemistry of Health and Disease</td>
<td>W</td>
<td>4 credits</td>
<td>2S</td>
<td>V. Korkhov, T. Ishikawa, M. Jagannathan, R. Kroschewski, G. Neurohr, M. Peter, A. E. Smith, B. Snijder, K. Weis</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 20.</td>
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</table>

Abstract
During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.

Objective
Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to introduce, present, evaluate, critically discuss and write about recent scientific articles in the research area of cellular biochemistry.

Content
Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with occasional frontal presentations. Students will alternate as discussion leaders throughout the semester, with the student leader responsible to briefly summarize key general knowledge and context of the assigned primary research paper. Together with the faculty expert, all students will participate in discussion of the primary paper, including the foundation of the biological question, specific questions addressed, key methods, key results, remaining gaps and research implications.

Literature
The literature will be provided during the course

Prerequisites / notice
The course will be taught in English.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0512-00L</td>
<td>Current Topics in Molecular and Cellular Neurobiology</td>
<td>W</td>
<td>2 credits</td>
<td>1S</td>
<td>U. Suter</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Number of participants limited to 8.</td>
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</table>

Abstract
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

Objective
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.
Content
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

You are expected to participate in the discussion and ask questions. To prepare for this you should read all the papers beforehand (they will be announced a week in advance of the presentation).

Presentations will be available after the seminars.

Lecture notes

Prerequisites / notice
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

551-1153-00L Systems Biology of Metabolism

Number of participants limited to 15.

Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

Script and original publications will be supplied during the course.

551-1177-00L ImmunoLOGY: From Milestones to Current Topics

Milestones in Immunology: on old concepts and modern experiments

The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, myeloid cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the debate. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.

Original and review articles will be distributed by the respective lecturer.

Literature
Literaturunterlagen werden vor Beginn des Kurses auf folgender website zugänglich sein: https://moodle- app2.let.ethz.ch/course/view.php?id=15568

572-5000-00L Microbiology of Foodborne Pathogens

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococci). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students. Recommendations will be given in the first lecture.

Autumn Semester 2021 Page 298 of 2152
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

The focus is on primary literature, but for some parts the following text books provide good background information:

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

**Prerequisites / notice**

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

752-6101-00L

**Dietary Etiologies of Chronic Disease**

**W 3 credits 2V**

M. B. Zimmermann

**Abstract**

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**

There is no script. Powerpoint presentations will be made available on-line to students.

**Literature**

To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**

No compulsory prerequisites, but prior completion of the courses “Introduction to Nutritional Science” and “Advanced Topics in Nutritional Science” is strongly advised.

376-0300-00L

**Translational Science for Health and Medicine**

**W 3 credits 2G**

J. Goldhahn, C. Wolfrum

**Abstract**

Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

**Objective**

After completing this course, students will be able to understand:

- Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)

**Content**

What is translational science and what is it not?

- Disease concepts and consequences for research
- Basics about incidence, prevalence etc., and orphan indications
- How to choose the appropriate research type and methodology
- Ethical considerations including ethics application
- Pros and cons of different types of research
- Coordination of complex approaches incl. timing and resources
- How to measure success?
- Outcome variables
- Improving the translational process
- Challenges of communication?
- How independent is translational science?
- Academic boundary conditions vs. industrial influences

Positive and negative examples will be illustrated by distinguished guest speakers.

701-1703-00L

**Evolutionary Medicine for Infectious Diseases**

**W 3 credits 2G**

A. Hall

**Abstract**

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

**Objective**

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

**Content**

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

**Literature**

The focus is on primary literature, but for some parts the following text books provide good background information:

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine

**Prerequisites / notice**

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

636-0108-00L

**Biological Engineering and Biotechnology**

**W 4 credits 3V**

M. Fussenegger

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**


**Lecture notes**

Handout during the course.

551-1407-00L

**RNA Biology Lecture Series I: Transcription & Processing & Translation**

**W 4 credits 2V**

F. Allain, N. Ban, U. Kutay, further lecturers

**Abstract**

This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

**Objective**

The students should obtain an understanding of these processes, which are at work during gene expression.
### 551-1409-00L RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>O</td>
<td>3</td>
<td>2</td>
<td>U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp</td>
</tr>
</tbody>
</table>

**Abstract**

The course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

**Objective**

The students will learn about the methods used to study non-coding RNAs, computational approaches to miRNAs, micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; TRNA biology.

**Prerequisites / notice**

Basic knowledge of cell and molecular biology.

### 551-1423-00L Current Topics in Metabolism and Disease

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0319-00L</td>
<td>Current Topics in Metabolism and Disease Does not take place this semester</td>
<td>O</td>
<td>2</td>
<td>1S</td>
<td>to be announced</td>
</tr>
</tbody>
</table>

**Abstract**

The course introduces the students to recent developments in the fields of metabolism and disease. It also supports the development of analytical skills, including critical reading of scientific literature, being able to present and critically discuss scientific experiments, point out technical limitations, and placing recent discoveries in the broader context of biology, physiology and medicine. The students should be able to grasp what the authors wanted to learn i.e. their hypothesis and goals, why the authors chose the experimental approach and methods used, the strengths and weaknesses of the experiments, the quality of the data presented, the conclusions drawn, and how the work fits into the wider literature in the field. Furthermore, the student should discuss alternative approaches and future experiments. Each student will present one paper during the course, which provides him/her with practice in public speaking.

**Objective**

Each student will present at least once during the semester. The presentation includes an introduction to the field of the paper, a critical description of the main results, a summary of the main points and a discussion of their significance. Each participant is expected to take part in the discussion and to ask questions. At each meeting, all students are expected to read the paper beforehand. Each paper presented will be announced one week in advance of the presentation.

**Prerequisites / notice**

Literature

Presentations will be made available after the seminars.

**Type**

Students will be guided to choose their papers based on recent literature published less than 1 year prior in a relevant journal.

### Elective Major: Biochemistry

#### Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
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<td>O</td>
<td>3</td>
<td>2</td>
<td>U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp</td>
</tr>
</tbody>
</table>

**Abstract**

The course is a literature seminar or "journal club". Each Friday a student, or a member of the Stoffel Lab in the Institute of Molecular Health Sciences, will present a comprehensive presentation of a recent paper published in a top ranking international peer reviewed journal that relates to metabolism and disease.

**Objective**

The course introduces the students to recent developments in the fields of metabolism and disease. It also supports the development of analytical skills, including critical reading of scientific literature, being able to present and critically discuss scientific experiments, point out technical limitations, and placing recent discoveries in the broader context of biology, physiology and medicine. The students should be able to grasp what the authors wanted to learn i.e. their hypothesis and goals, why the authors chose the experimental approach and methods used, the strengths and weaknesses of the experiments, the quality of the data presented, the conclusions drawn, and how the work fits into the wider literature in the field. Furthermore, the student should discuss alternative approaches and future experiments. Each student will present one paper during the course, which provides him/her with practice in public speaking.

**Content**

Each student will present at least once during the semester. The presentation includes an introduction to the field of the paper, a critical description of the main results, a summary of the main points and a discussion of their significance. Each participant is expected to take part in the discussion and to ask questions. At each meeting, all students are expected to read the paper beforehand. Each paper presented will be announced one week in advance of the presentation.

**Prerequisites / notice**

**Type**

Students will be guided to choose their papers based on recent literature published less than 1 year prior in a relevant journal.

#### Compulsory Master Course

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1303-00L</td>
<td>Cellular Biochemistry of Health and Disease Number of participants limited to 20.</td>
<td>O</td>
<td>4</td>
<td>2S</td>
<td>V. Korkhov, T. Ishikawa, M. Jagannathan, R. Kroschewski, G. Neurohr, M. Peter, A. E. Smith, B. Snijder, K. Weis</td>
</tr>
</tbody>
</table>

**Abstract**

During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.

**Objective**

Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to introduce, present, evaluate, critically discuss and write about recent scientific articles in the research area of cellular biochemistry.

**Content**

Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with occasional frontal presentations. Students will alternate as discussion leaders throughout the semester, with the student leader responsible to briefly summarize key general knowledge and context of the assigned primary research paper. Together with the faculty expert, all students will participate in discussion of the primary paper, including the foundation of the biological question, specific questions addressed, key methods, key results, remaining gaps and research implications.

**Prerequisites / notice**

The literature will be provided during the course

The course will be taught in English.

### Elective Compulsory Concept Courses

Autumn Semester 2021
Page 300 of 2152
Molecular and Structural Biology I: Protein Structure and Function

**Abstract**
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

**Objective**
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

**Lecture notes**
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

**Literature**
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

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**Concepts in Modern Genetics**

**Abstract**
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Objective**
This course focuses on the concepts of classical and modern genetics and genomics.

**Content**
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**
Scripts and additional material will be provided during the semester.

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**Elective Compulsory Master Courses**

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
551-0307-00L | Molecular and Structural Biology I: Protein Structure and Function | W | 3 credits | 2V | R. Glockshuber, K. Locher, E. Weber-Ban

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
551-0309-00L | Concepts in Modern Genetics | W | 6 credits | 4V | Y. Barral, D. Bopp, A. Hajnal, O. Voinnet

---

**Enrolment to module BIO348 at UZH.**

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

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**Prerequisites / Literature**

**Enzymes**
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.
- Creighton, T.E., Proteins, Freeman, (1993)

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**Prerequisites / Literature**

**Systems Biology of Metabolism**
- Number of participants limited to 15.
- Information for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

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**Prerequisites / Literature**

**Computational Systems Biology**
- Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

---

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

401-0649-00L

**Content**

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

**Literature**

- Fox (2008): *Applied Regression Analysis and GLMs*
- Montgomery et al. (2006): *Introduction to Linear Regression Analysis*

**Prerequisites / notice**

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Taught competencies**

- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed
  - Project Management: not assessed
- Domain C - Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed
- Domain D - Personal Competencies
  - Adaptability and Flexibility: assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed

529-0041-00L

**Content**

Modern mass spectrometry, hyphenated methods, and chemometrics.

**Abstract**

Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

**Objective**

Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

**Content**

Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

**Lecture notes**

Lecture notes will be made available online.

**Literature**

Information about relevant literature will be available in the lecture & in the lecture notes.

**Prerequisites / notice**

Exercises are an integral part of the lecture. Prerequisites:
- 529-0051-00 "Analytische Chemie I (3. Semester)"
- 529-0058-00 "Analytische Chemie II (4. Semester)" (or equivalent)
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.
Content

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature


Prerequisites / notice

Participants need a good command of

- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

Elective Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher,</td>
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<td></td>
<td>D-BIOL students are obliged to take part I and part II (next</td>
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<td>E. Weber-Ban</td>
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<td>semester) as a two-semester course</td>
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<tr>
<td>Abstract</td>
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<td>microanalytics.</td>
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<td>Lecture</td>
<td>Scripts on the individual topics can be found under</td>
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<tr>
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<td>- Creighton, T.E., Proteins, Freeman, (1993)</td>
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<td>Current topics: References will be given during the lectures.</td>
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<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
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<td>special-students-university-of-zurich.html</td>
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</tbody>
</table>
### 551-0313-00L Microbiology (Part I)

- **Abstract**: Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- **Objective**: This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- **Content**: Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.
- **Lecture notes**: Scripts and additional material will be provided during the semester.
- **Prerequisites / notice**: The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

### 551-0317-00L Immunology I

- **Abstract**: Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.
- **Objective**: Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.
- **Content**: - Introduction and historical background - Innate and adaptive immunity, Cells and organs of the immune system - B cells and antibodies - Generation of diversity - Antigen presentation and Major Histoincompatibility (MHC) antigens - Thymus and T cell selection - Autoimmunity - Cytotoxic T cells and NK cells - Th1 and Th2 cells, regulatory T cells - Allergies - Hypersensitivities - Vaccines, immune-therapeutic interventions
- **Literature**: - Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020
- **Prerequisites / notice**: For D-BiOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

### 529-0731-00L Nucleic Acids and Carbohydrates

- **Abstract**: Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines
- **Objective**: Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines
- **Content**: Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines
- **Literature**: Mainly based on original literature, a detailed list will be distributed during the lecture.
<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
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</thead>
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<tr>
<td></td>
<td>Concepts and Theories</td>
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<td>Analytical Competencies</td>
<td>Problem-solving</td>
<td>Cooperation and Teamwork</td>
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<td>Self-direction and Self-management</td>
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**Elective Major: Molecular Plant Biology**

**Compulsory Master Courses**

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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**Compulsory Concept Courses**

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<tr>
<th>Number</th>
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**Elective Compulsory Concept Courses**

See D-BIOL Master Studies Guide

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<td>3</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Ban</td>
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</tbody>
</table>

**Abstract**
The advanced course introduces students to plants through a concept-based discussion of developmental processes that integrates physiology and biochemistry with genetics, molecular biology, and cell biology. The course follows the life of the plant, starting with the seed, progressing through germination to the seedling and mature plant, and ending with reproduction and senescence.

**Objective**
The new course "Molecular Life of Plants" reflects the rapid advances that are occurring in the field of experimental plant biology as well as the changing interests of students being trained in this discipline. Contemporary plant biology courses emphasize a traditional approach to experimental plant biology by discussing discrete topics that are removed from the context of the plant life cycle. The course will take an integrative approach that focuses on developmental concepts. Whereas traditional plant physiology courses were based on research carried out on intact plants or plant organs and were often based on phenomenological observations, current research in plant biology emphasizes work at the cellular, subcellular and molecular levels.

The goal of "Molecular Life of Plants" is to train students in integrative approaches to understand the function of plants in a developmental context. While the course focuses on plants, the training integrative approaches will also be useful for other organisms.

**Content**
The course "Molecular Life of Plants" will cover the following topics:

- Plant genome organization and evolution
- Plant functional genomics and systems biology
- Plant genome engineering and editing
- Seed development and embryogenesis
- Root apical meristem: structure, function and hormone regulation
- Shoot apical meristem: structure, function and hormone regulation
- Mobilization of seed reserves
- Heterotrophic to autotrophic growth
- Chloroplast biogenesis and light perception
- Photosynthetic and central carbon metabolism
- Integration of carbon and nitrogen metabolism
- Principles of RNA silencing
- MicroRNAs: discovery and modes of action
- RNA silencing and pathogen defense
- RNA silencing movement, amplification and trans-generational silencing
- Plants and the environment
- Plant-pathogen interactions: pathogen attack, first layers of plant defense and plant responses
- Senescence

Current topics: References will be given during the lectures.

**Compulsory Course List**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

**Abstract**
Current topics in Molecular Plant Biology presented by internal and external speakers from academia.

**Objective**
Getting insight into actual areas and challenges of Molecular Plant Biology.

**Content**
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
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<th>Credits</th>
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<tr>
<td>551-0309-00L</td>
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<td>Information for UZH students:</td>
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<td>Barral, D. Bopp, A. Hajnal, O. Voinnet</td>
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<tr>
<td>Abstract</td>
<td>Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<tr>
<td>Objective</td>
<td>This course focuses on the concepts of classical and modern genetics and genomics.</td>
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<td>Content</td>
<td>The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<tr>
<td>Lecture notes</td>
<td>Scripts and additional material will be provided during the semester.</td>
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<tr>
<td>551-0313-00L</td>
<td>Microbiology (Part I)</td>
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<td>Hardt, L. Eberl, J. Piel, M. Pilofer</td>
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<tr>
<td>Abstract</td>
<td>Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td>Objective</td>
<td>This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.</td>
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<td>Content</td>
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<tr>
<td>Lecture notes</td>
<td>Updated handouts will be provided during the class.</td>
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<tr>
<td>Literature</td>
<td>Current literature references will be provided during the lectures.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>English. The lecture &quot;Grundlagen der Biologie II: Mikrobiologie&quot; is the basis for this advanced lecture.</td>
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<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
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<td>Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp</td>
</tr>
<tr>
<td>Abstract</td>
<td>Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division &amp; growth, and cell migration.</td>
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<tr>
<td>Objective</td>
<td>The full-year course (551-0319-00 &amp; 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular proteins, enzymes or pathways involved in cellular processes such as cancer.</td>
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<tr>
<td>Content</td>
<td>Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.</td>
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<tr>
<td>Lecture notes</td>
<td>Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (<a href="mailto:alicia.smith@bc.biol.ethz.ch">alicia.smith@bc.biol.ethz.ch</a>)</td>
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<tr>
<td>Literature</td>
<td>Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.</td>
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<tr>
<td>701-2413-00L</td>
<td>Evolutionary Genetics</td>
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<td></td>
<td>Städerl, A. Widmer, S. Fior, M. C. Fischer, J. Stapley</td>
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<tr>
<td>Abstract</td>
<td>The concept course 'Evolutionary Genetics' consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).</td>
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<tr>
<td>Objective</td>
<td>The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.</td>
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<tr>
<td>Content</td>
<td>Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory. Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding; effects on fitness; Fisher's fundamental theorem. Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.</td>
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<tr>
<td>Lecture notes</td>
<td>Handouts</td>
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<tr>
<td>529-0731-00L</td>
<td>Nucleic Acids and Carbohydrates</td>
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<td>Hilvert, P. A. Kast, S. J. Sturza, H. Wernermers</td>
</tr>
<tr>
<td>Abstract</td>
<td><strong>Note for BSc Biology students:</strong> Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.</td>
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<tr>
<td>Objective</td>
<td>Structure, function and chemistry of nucleic acids and carbohydrates, DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines.</td>
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<td>Content</td>
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</table>

**Data:** 14.12.2021 12:41  
**Autumn Semester 2021**  
**Page 307 of 2152**
Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.

### Elective Compulsory Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>751-4801-00L</td>
<td>System-Oriented Management of Herbivore Insects</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>to be announced</td>
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<tr>
<td>529-0733-01L</td>
<td>Enzymes</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>D. Hilvert</td>
</tr>
<tr>
<td>751-5121-00L</td>
<td>Insect Ecology</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. De Moraes, M. Mescher, N. Stanczyk</td>
</tr>
<tr>
<td>551-1153-00L</td>
<td>Systems Biology of Metabolism</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni, M. Zampieri</td>
</tr>
<tr>
<td>751-4504-00L</td>
<td>Plant Pathology I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>B. McDonald</td>
</tr>
</tbody>
</table>

In addition, citations from the original literature relevant to the individual lectures will be assigned weekly.

**Abstract**

- The students gain a good understanding of fundamental aspects of pest management in agroecosystems. They will be able to assess options for action in view of requirements from the economy, environment and society. Further, they will learn to elaborate on current issues in pest management, and to critically evaluate case studies.
- The students gain a good understanding of fundamental aspects of pest management in agroecosystems. They will be able to assess options for action in view of requirements from the economy, environment and society. Further, they will learn to elaborate on current issues in pest management, and to critically evaluate case studies.

**Objective**

- Development of a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.
- Development of a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.

**Literature**

- Provided to students through Moodle.
- A script will not be handed out.
- Selected required readings (peer reviewed literature). Optional recommended readings with additional information.
- The number of participants is limited to 30.

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**Data:** 14.12.2021 12:41  
**Autumn Semester 2021**  
**Page:** 308 of 2152
Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease development in agroecosystems. Themes will include: 1) how pathogens attack plants and 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third theme will include the disease triangle and cultural control strategies.

**Lecture Topics and Tentative Schedule**

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

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

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

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

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

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

**Week 7**  

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

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

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

**Week 11**  

**Week 12**  

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

**Week 14**  
Open lecture.

Lecture notes  
Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

### Elective Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>
| 551-0307-00L   | Molecular and Structural Biology I: Protein Structure and Function  

D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course  

Abstract: Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective: Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes: Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.  

Autumn Semester 2021  
Page 309 of 2152
Current topics: References will be given during the lectures.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, D. Bopp, A. Hajnal, O. Voinnet</td>
</tr>
</tbody>
</table>

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

551-0313-00L | Microbiology (Part I) | W    | 3    | 2V    | W.-D. Hardt, L. Eberl, J. Piel, M. Pilhofer |

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-0319-00L | Cellular Biochemistry (Part I) | W    | 3    | 2V    | U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp |

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content
The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Lecture notes
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

**ELECTIVE MAJOR: SYSTEMS BIOLOGY**

**ELECTIVE COMPULSORY CONCEPT COURSES**

*See D-BIOL Master Studies Guide*

Computational Systems Biology
This course focuses on the concepts of classical and modern genetics and genomics.

W., D. Bopp, A. Hajnal,

This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover

Introduction to Bioinformatics

Hours
Microbiology (Part I)
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

2V
The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging.

Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Lecture notes

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/program-courses/special-students/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes

551-0313-00L
Microbiology (Part I) W 3 credits 2V W.-D. Hardt, L. Eberl, J. Piel, M. Pilhofer
Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes

Updated handouts will be provided during the class.

Literature

Current literature references will be provided during the lectures.

Prerequisites / notice

The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-1299-00L
Abstract
This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include:
genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming.

Objective
The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data.

Content
Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation
Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice

Course participants have already acquired basic programming skills in Python and R.

Students will bring and work on their own laptop computers, preferentially running the latest versions of Windows or MacOSX.

Elective Compulsory Master Courses I: Computation

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0007-00L</td>
<td>Computational Systems Biology</td>
<td>W</td>
<td>6</td>
<td>3V+2U</td>
<td>J. Stelling</td>
</tr>
<tr>
<td>Abstract</td>
<td>Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).</td>
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<tr>
<td>Objective</td>
<td>The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.</td>
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</table>
Content
Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label “Systems Biology”, focuses on how networks, which are more than the mere sum of their parts’ properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes
http://www.csb.ethz.ch/education/lectures.html

Literature

636-0706-00L Spatio-Temporal Modelling in Biology

Abstract
This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

Objective
Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content
1. Introduction to Modelling in Biology
2. Morphogen Gradients
3. Dynamical Systems
4. Cell-cell Signalling (Dr Boaretto)
5. Travelling Waves
6. Turing Patterns
7. Chemotaxis
8. Mathematical Description of Growing Biological Systems
9. Image-Based Modelling
10. Tissue Mechanics
11. Cell-based Tissue Simulation Frameworks
12. Plant Development (Dr Dumont)
13. Growth Control
14. Summary

Lecture notes
All lecture material will be made available online
https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html

Literature
The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

Murray, Mathematical Biology, Springer
Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
Keener and Sneyd, Mathematical Physiology, Springer
Fall et al. Computational Cell Biology, Springer
Szallasi et al, System Modeling in Cellular Biology, MIT Press
Wolkenhauer, Systems Biology
Kreyszig, Engineering Mathematics, Wiley

Prerequisites / notice
The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

Elective Compulsory Master Courses II: Biology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1153-00L</td>
<td>Systems Biology of Metabolism</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Sauer, N. Zamboni, M. Zampieri</td>
</tr>
</tbody>
</table>

Abstract
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

Objective
The course will be given as a mixture of lectures, original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.

Lecture notes
Script and original publications will be supplied during the course.

Prerequisites / notice
The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0571-00L</td>
<td>From DNA to Diversity (University of Zurich)</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Hajnal, D. Bopp</td>
</tr>
</tbody>
</table>

Abstract
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.
**Objective**

By the end of this course, students should be able to:
- recognize the universal principles underlying the development of different animal body plans.
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.
- relate changes in gene structure or function to evolutionary changes in animal development.

**Key skills:**
- By the end of this module, each student should be able to:
- present and discuss a relevant evolutionary topic in an oral presentation.
- select and integrate key concepts in animal evolution from primary literature.
- participate in discussions on topics presented by others.

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**636-0009-00L**  
**Evolutionary Dynamics**  
**W 6 credits 2V+1U+2A**  
**N. Beerenwinkel**

**Abstract**

Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.

**Objective**

The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

**Content**

Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.

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**Lecture notes**

No.


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**227-0939-00L**  
**Cell Biophysics**  
**W 6 credits 4G**  
**T. Zambelli**

**Abstract**

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

**Objective**

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann's law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytokskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

**Content**

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elastcity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

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**Lecture notes**

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

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**Literature**

Prerequisites / notice
Participants need a good command of
• differentiation and integration of a function with one or more variables (basics of Analysis),
• Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Subject-specific Competencies</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concepts and Theories</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Barr</td>
</tr>
<tr>
<td>A</td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
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<tr>
<td>B</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td>B</td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td>B</td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<tr>
<td>B</td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>B</td>
<td>Project Management</td>
<td>assessed</td>
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<tr>
<td>C</td>
<td>Communication</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>D</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td>D</td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

Notions of vectors in 2D and 3D are beneficial.

Elective Major: Molecular and Structural Biology

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Glockshuber, K. Locher, E. Weber-Barr</td>
</tr>
</tbody>
</table>

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytis.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

Elective Compulsory Concept Courses

See D-BIOL Master Studies Guide

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp</td>
</tr>
</tbody>
</table>

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.
Abstract
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Objective
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature
Mainly based on original literature, a detailed list will be distributed during the lecture.

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies
- Self-awareness and Self-reflection
- Self-direction and Self-management

551-0313-00L Microbiology (Part I) W 3 credits 2V W.-D. Hardt, L. Eberli, J. Piel, M. Pilhofer

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
English
The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

551-0309-00L Concepts in Modern Genetics W 6 credits 4V Y. Barral, D. Bopp, A. Hajnal, O. Voinnet

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.


Abstract
This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include: genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming.

Objective
The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifiability of a person and the ownership of data.

Content
Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation
Automatic analysis of drug effects on single cell suspension (chemotyping)
## Elective Compulsory Master Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0733-01L</td>
<td>Enzymes</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>D. Hilvert</td>
</tr>
<tr>
<td>Abstract</td>
<td>Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme-catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Overview of enzymes, enzyme-catalyzed reactions and metabolic processes.</td>
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</tr>
<tr>
<td>Content</td>
<td>Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.</td>
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</tr>
<tr>
<td>Literature</td>
<td>In addition, citations from the original literature relevant to the individual lectures will be assigned weekly.</td>
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</tbody>
</table>

| 551-1401-00L   | Advanced Protein Engineering (University of Zurich) | W    | 2 credits | 2G    | University lecturers |
| Number of participants limited to 15. |
| Abstract       | No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. |
| UZH Module Code: BCH420 |
| Objective      | Introduction into current research strategies in protein science. |
| Content        | To understand current research strategies in protein science. |
| Lecture notes  | Slides and references will be available on OLAT server. |
| Literature     | PDFs will be available on OLAT server. |

| 551-1153-00L   | Systems Biology of Metabolism                   | W    | 4 credits | 2V    | U. Sauer, N. Zamboni, M. Zampieri |
| Number of participants limited to 15. |
| Abstract       | Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts. |
| Objective      | Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology. |
| Content        | The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation networks in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics. |
| Lecture notes  | Script and original publications will be supplied during the course. |
| Prerequisites / notice | The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry. |

| 529-0004-01L   | Classical Simulation of (Bio)Molecular Systems   | W    | 6 credits | 4G    | P. H. Hünenberger, J. Dolenc, S. Riniker |
| Number of participants limited to 15. |
| Abstract       | Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS). |
| Objective      | Introduction to classical (atomicistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations. |
| Content        | Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS). |
| Lecture notes  | The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture). |
| Literature     | See: www.csms.ethz.ch/education/CSBMS |
| Prerequisites / notice | Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark). |

| 401-0649-00L   | Applied Statistical Regression                   | W    | 5 credits | 2V+1U | M. Detting |
| Abstract       | This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis. |
| Objective      | The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling. |
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Concepts and Theories

Domain A - Subject-specific Competencies

Taught competencies

Domain B - Method-specific Competencies

Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Prerequisites / notice

Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

The course is offered during the second part of the semester and which can be taken independently from Part I.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

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

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

Prerequisites / notice

An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

The course resources will be provided via the Moodle web learning platform. As from FS 2019, subscribing via Mystudies should "automatically" make you a student participant of the Moodle course of this lecture, which is at

https://moodle-app2.let.ethz.ch/course/view.php?id=15518
This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

Prerequisites / notice
Exercises are an integral part of the lecture.

Prerequisites:
529-0051-00 *Analytische Chemie I (3. Semester)*
529-0058-00 *Analytische Chemie II (4. Semester)*
(or equivalent)

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<th>RNA Biology Lecture Series I: Transcription &amp; Processing &amp; Translation</th>
<th>W</th>
<th>4 credits</th>
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<td>Objective</td>
<td>The students should obtain an understanding of these processes, which are at work during gene expression.</td>
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<tr>
<td>Content</td>
<td>Transcription &amp; 3’end formation; splicing, alternative splicing, RNA editing; the ribosyme &amp; translation, translation regulation, RNP biogenesis &amp; nuclear export, miRNA surveillance &amp; miRNA turnover; signal transduction &amp; RNA.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basic knowledge of cell and molecular biology.</td>
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<td>551-1409-00L</td>
<td>RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics</td>
<td>W</td>
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<td>Objective</td>
<td>The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.</td>
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<tr>
<td>Content</td>
<td>Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomerases; tRNA biology.</td>
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<tr>
<td>Prerequisites / notice</td>
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<td>227-0939-00L</td>
<td>Cell Biophysics</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
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<tr>
<td>Objective</td>
<td>Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.</td>
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<tr>
<td>Content</td>
<td>Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.</td>
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<tr>
<td>Content</td>
<td>By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.</td>
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• Basics of theory of probability
• Boltzmann's law
• Entropy maximization and Gibbs free energy minimization
• Ligand-receptor: two-state systems and the MWC model
• Random walks, diffusion, crowding
• Electrostatics for salty solutions
• Elasticity: fibers and membranes
• Molecular motors
• Action potential: Hodgkin-Huxley model
• Photosynthesis and vision
• Gene regulation
• Development: Turing patterns
• Sequences and evolution

Theory and corresponding exercises are merged together during the classes.
### Elective Major: Biological Chemistry

#### Elective Compulsory Concept Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

**Abstract**
Structure, function and chemistry of nucleic acids and carboxydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Objective**
Structure, function and chemistry of nucleic acids and carboxydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Content**
Structure, function and chemistry of nucleic acids and carboxydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

**Lecture notes**
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

**Literature**
Mainly based on original literature, a detailed list will be distributed during the lecture.

**Taught competencies**

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#### Elective Compulsory Master Courses

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<tbody>
<tr>
<td>529-0733-01L</td>
<td>Enzymes</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>D. Hilvert</td>
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</table>

**Abstract**
Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme-catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

**Objective**
Overview of enzymes, enzyme-catalyzed reactions and metabolic processes.

**Content**
Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme catalysis reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

**Lecture notes**
A script will not be handed out.
### 529-0004-01L Classical Simulation of (Bio)Molecular Systems

**W** 6 credits  4G  P. H. Hünenberger, J. Dolenc, S. Rinkler

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- Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

- Introduction to classical (atomic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

- Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

For more information about the lecture: [www.csms.ethz.ch/education/CSBMS](http://www.csms.ethz.ch/education/CSBMS)

### 529-0233-01L Organic Synthesis: Methods and Strategies

**W** 6 credits  3G  E. M. Carreira

- The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

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For more information about the lecture: [www.csms.ethz.ch/education/CSBMS](http://www.csms.ethz.ch/education/CSBMS)

### 529-0243-01L Transition Metal Catalysis: From Mechanisms to Applications

**W** 6 credits  3G  B. Morandi

- Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint

- Understanding and critical evaluation of current research in transition metal catalysis. Design of mechanistic experiments to elucidate reaction mechanisms. Synthetic relevance of transition metal catalysis. Students will also learn about writing an original research proposal during a workshop.

- Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, redox active ligands, main group redox catalysis, bimetallic catalysis.

- Slides will be uploaded 1-2 days before each lecture on [http://morandi.ethz.ch/education.html](http://morandi.ethz.ch/education.html)

- Primary literature and review articles will be cited during the course.

- The following textbooks can provide useful support for the course:

- Required level: Courses in organic and physical chemistry (kinetics in particular) of the first and second year as well as ACIII

- Special requirement: each participant will have to come up with an independent research proposal to be presented orally (or handed in in written form) at the end of the semester. A dedicated workshop will be organized in the middle of the semester to introduce the students to proposal writing and presentation.
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation. 

**Abstract**

Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

**Content**

Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

**Lecture notes**

Lecture notes will be made available online.

**Literature**

Information about relevant literature will be available in the lecture & in the lecture notes.

**Prerequisites / notice**

Exercises are an integral part of the lecture.

**Taught competencies**

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

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

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

**551-1407-00L**  
**RNA Biology Lecture Series I: Transcription & Processing & Translation**  
**W 4 credits 2V**  
**F. Allain, N. Ban, U. Kutay, further lecturers**

**Abstract**

This course covers aspects of RNA biology related to gene expression at the posttranscriptional level. These include RNA transcription, processing, alternative splicing, editing, export and translation.

**Objective**

The students should obtain an understanding of these processes, which are at work during gene expression.

**Content**

Transcription & 3'end formation; splicing, alternative splicing, RNA editing; the ribosome & translation, translation regulation, RNP biogenesis & nuclear export, miRNA surveillance & miRNA turnover; signal transduction & RNA.

**Prerequisites / notice**

Basic knowledge of cell and molecular biology.

**551-1409-00L**  
**RNA Biology Lecture Series II: Non-Coding RNAs:**  
**W 4 credits 2V**  
**J. Hall, M. Stoffel, further lecturers**

**Abstract**

This course covers aspects of RNA biology related to the functions of non-coding RNAs as well as their use as drugs to treat diseases.

**Objective**

The students should get familiar with the wide array of roles, which non-coding RNAs play in cellular functions.

**Content**

Micro RNAs; computational approaches to miRNAs; micro RNA function in metabolism; viruses and viral RNAs; nucleic acid-based drugs; ncRNA-mediated genome regulation; epigenetic programming of genome remodelling in ciliates; telomerase and telomeres; tRNA biology.

### Advanced Methods and Strategies in Synthesis

**Abstract**

Knowledge of modern methods in asymmetric stereocontrol, enantioselective catalysis, and organic reaction mechanisms.

**Objective**

Current trends in methods for and approaches to synthesis of complex natural products, pharmaceuticals, and biological molecules; fragment coupling and protecting group strategies; chemical ligation and biomolecules synthesis; enantioselective catalysis including ligand design and optimization; cross coupling reactions from preactivated precursors; C-H activation and oxidation chemistry; building block synthesis with chiral auxiliaries and reagents; new concepts in asymmetric catalysis. Analysis of key primarily literature including identification of trends, key predecessors, and emerging topics will be emphasized.

**Lecture notes**

will be provided in class and online

**Literature**

Suggesting Textbooks


### Cell Biophysics

**Abstract**

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

**Objective**

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

**Content**

- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

**Lecture notes**

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

**Literature**


**Prerequisites / notice**

Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.
Taught competencies

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#### Elective Concept Courses

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<tr>
<td>551-0307-00L</td>
<td>Molecular and Structural Biology I: Protein Structure and Function</td>
<td>W</td>
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<td>R. Glockshuber, K. Locher, E. Weber-Bar</td>
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<td>551-0319-00L</td>
<td>Cellular Biochemistry (Part I)</td>
<td>W</td>
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<td>U. Kutay, G. Neurolhr, M. Peter, K. Weis, I. Zemp</td>
</tr>
</tbody>
</table>

**Abstract**
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNA, current topics in protein biophysics and structural biology.

**Objective**
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

**Lecture notes**
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

**Literature**
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

**Abstract**
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalization of biochemical processes.

**Lecture notes**
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bcc.biol.ethz.ch)

**Literature**
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

**Prerequisites / notice**
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.
Content
Ethics:
Case studies to learn about applying ethical principles in human genomics research

Genomics:
Genetic variant calling
Analysis and critical evaluation of genome wide association studies

Metagenomics:
Reconstruction of microbial genomes
Microbial community compositional analysis
Quantitative metagenomics

Network bioinformatics:
Inference of molecular networks
Use of networks for interpretation of (gen)omics data

Imaging:
High throughput single cell imaging
Image segmentation

Automatic analysis of drug effects on single cell suspension (chemotyping)

Prerequisites / notice
Course participants have already acquired basic programming skills in Python and R.

Students will bring and work on their own laptop computers, preferably running the latest versions of Windows or MacOSX.

Recommended Elective Courses (for all Master Majors)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0180-00L</td>
<td>Research Ethics</td>
<td>W+</td>
<td>2 credits</td>
<td>2G</td>
<td>G. Achermann, P. Emch</td>
</tr>
</tbody>
</table>

Number of participants limited to 40

Particularly suitable for students of D-BIOL, D-CHAB, D-HEST

Abstract
Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective
Participants of the course Research Ethics will
• Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
• Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;

Content
I. Introduction to Moral Reasoning
1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity
1.5 Selection of study participants – the concept of vulnerability
1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.
Prerequisites / notice

What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):

1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…)

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

Research Projects (for all Master Majors)

Research projects neither accepted nor registered nor approved will not be credited.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1801-00L</td>
<td>Research Project I</td>
<td>O</td>
<td>15 credits</td>
<td>34A</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.</td>
<td></td>
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<td></td>
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<tr>
<td>551-1801-01L</td>
<td>Research Project II</td>
<td>O</td>
<td>15 credits</td>
<td>34A</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.</td>
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</table>

GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-BIOL.

Master’s Thesis

A Master’s thesis neither accepted nor registered nor approved will not be credited.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1800-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>
| Abstract | Only students who fulfill the following criteria are allowed to begin with their master thesis:
a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme;
c. have acquired at least 30 credits in the category “research projects”.
| | The Master research will be carried out on a theme in the chosen subject area and must be completed with a written report (Thesis) within six months |

Master’s Examination

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1800-01L</td>
<td>Master's Examination</td>
<td>O</td>
<td>4 credits</td>
<td></td>
<td>Lecturers</td>
</tr>
</tbody>
</table>
| Abstract | Only students who fulfill the following criteria are admitted for the master examination:
a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme. |
| | In the Master’s examination a student must provide proof of general knowledge in the elective major field. Starting with a discussion based on the Master’s thesis further experiments and experimental strategies should be discussed in order to test the general understanding. |

Biology Master - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>Compulsory</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
</tr>
</tbody>
</table>
### Key for Hours

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

**ECTS**

- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Microrobotics

Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

The course is taught in English.

The lecture will be taught in English.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum

- From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.
- Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.
- Self-assembly and directed assembly of 2D and 3D structures.

(II) Interaction Forces on the Micro and Nano Scale


Course format:

- Lectures and Mini-Review presentations: Thursday 10-13
- Homework: Mini-Review (compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

Microsystems I: Process Technology and Integration

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and devices by a sequence of defined processing steps (process flow).

The course is taught in English.

The lecture will be taught in English.

Handouts (available online)
<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>- S.M. Sze: Semiconductor Devices, Physics and Technology</td>
</tr>
<tr>
<td>- W. Menz, J. Mohr, O. Paul: Microsystem Technology</td>
</tr>
<tr>
<td>- Hong Xiao: Introduction to Semiconductor Manufacturing Technology</td>
</tr>
<tr>
<td>- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerequisites: Physics I and II</td>
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<table>
<thead>
<tr>
<th>227-0105-00L Introduction to Estimation and Machine Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
</tr>
<tr>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
</tr>
<tr>
<td><strong>Content</strong></td>
</tr>
<tr>
<td>Review of probability theory;</td>
</tr>
<tr>
<td>basics of statistical estimation;</td>
</tr>
<tr>
<td>least squares and linear learning;</td>
</tr>
<tr>
<td>Hilbert spaces;</td>
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<tr>
<td>Gaussian random variables;</td>
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<tr>
<td>singular-value decomposition;</td>
</tr>
<tr>
<td>kernel methods, neural networks, and more</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
</tr>
<tr>
<td>Lecture notes will be handed out as the course progresses.</td>
</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
</tr>
<tr>
<td>solid basics in linear algebra and probability theory</td>
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<table>
<thead>
<tr>
<th>227-0311-00L Qubits, Electrons, Photons</th>
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</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
</tr>
<tr>
<td>In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electron transfer to photosynthesis).</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td>Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.</td>
</tr>
<tr>
<td>Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!</td>
</tr>
<tr>
<td>In this way, students will work out a robust quantum mechanics (theoretical!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.</td>
</tr>
<tr>
<td><strong>Content</strong></td>
</tr>
<tr>
<td>• Lagrangian and Hamiltonian: Symmetries and Poisson Brackets</td>
</tr>
<tr>
<td>• Postulates of QM: Hilbert Spaces and Operators</td>
</tr>
<tr>
<td>• Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator</td>
</tr>
<tr>
<td>• Spin: Qubits, Bloch Equations, and NMR</td>
</tr>
<tr>
<td>• Entanglement</td>
</tr>
<tr>
<td>• Symmetries and Corresponding Operators</td>
</tr>
<tr>
<td>• Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands</td>
</tr>
<tr>
<td>• Harmonic Oscillator: Creation and Annihilation Operators</td>
</tr>
<tr>
<td>• Identical Particles: Bosons and Fermions</td>
</tr>
<tr>
<td>• Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER</td>
</tr>
<tr>
<td>• Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
</tr>
<tr>
<td>No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
</tr>
<tr>
<td>• M. Le Bellac, &quot;Quantum Physics&quot;, 2011, Cambridge University Press</td>
</tr>
<tr>
<td>Supplementary material will be uploaded in Moodle.</td>
</tr>
</tbody>
</table>

As rigorous and profound presentation of the mathematical framework |
G. Dell’Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer |

As account of those formidable years |
G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc. |

The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II". |

A solid base of Analysis I & II as well as of Linear Algebra is really helpful. |

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in moodle!
### Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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**227-0385-10L Biomedical Imaging**
- **W** 6 credits 5G
- **S. Kozerke, K. P. Prüssmann**

**Abstract**
Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

**Objective**
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Content**
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Lecture notes**
Lecture notes and handouts

**Literature**
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Prerequisites / notice**
Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

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**227-0386-00L Biomedical Engineering**
- **W** 4 credits 3G
- **J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong**

**Abstract**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Objective**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

**Content**

Practical and theoretical exercises in small groups in the laboratory.

**Lecture notes**
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://ibb.ethz.ch/education/biomedical-engineering.html

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**227-0393-10L Bioelectronics and Biosensors**
- **W** 6 credits 2V+2U
- **J. Vörös, M. F. Yanik**

**Abstract**
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Objective**
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

Autumn Semester 2021
Page 329 of 2152
Deep Learning in Artificial and Biological Neuronal Networks

L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

The course requires an open attitude to the interdisciplinary approach of bioelectronics. The main goal of this course is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al., 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Lecture notes
The lecture slides will be provided as a PDF after each lecture.
This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or TensorFlow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

**Abstract**

Mathematical methods in signal processing and machine learning.

I. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.

II. Learning linear and nonlinear functions and filters: neural networks, kernel methods.

III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.

**Objective**

The course is an introduction to some basic topics in signal processing and machine learning.

**Content**


**Lecture notes**

Lecture notes.

**Prerequisites / notice**

- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

**Prerequisites / notice**

This course was replaced by "Introduction to Estimation and Machine Learning" and "Advanced Signal Analysis, Modeling, and Machine Learning".

**Abstract**

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enclaves and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

**Content**

This course consists of the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

**Abstract**

Introduction to molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.

2. The concept of biocompatibility.

3. Introduction into methodology used in biomaterials research and application.

4. Introduction to different material classes in use for medical applications.

**Content**

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Literature**

Handouts are deposited online (moodle).


(available online via ETH library)

Handouts and references therein.
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopsies.

▶▶▶ Recommended Elective Courses

These courses are particularly recommended for the Bioelectronics track. Please consult your track advisor if you wish to select other subjects.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0509-00L</td>
<td>Microscale Acoustofluidics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Dual</td>
</tr>
<tr>
<td>Abstract</td>
<td>In this lecture the basics, as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.</td>
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<tr>
<td>Objective</td>
<td>Understanding acoustophoresis, the design of devices and potential applications</td>
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</tr>
<tr>
<td>Content</td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies Concepts and Theories assessed</td>
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<td></td>
<td>Domain B - Method-specific Competencies Analytical Competencies assessed</td>
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<td></td>
<td></td>
<td>Decision-making not assessed</td>
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<td></td>
<td>Media and Digital Technologies not assessed</td>
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<td>Problem-solving assessed</td>
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<td>Project Management not assessed</td>
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<td>Domain C - Social Competencies Communication assessed</td>
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<td>Cooperation and Teamwork assessed</td>
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<td></td>
<td></td>
<td>Customer Orientation not assessed</td>
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<td></td>
<td>Leadership and Responsibility not assessed</td>
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<td>Self-presentation and Social Influence not assessed</td>
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<td>Sensitivity to Diversity not assessed</td>
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<td>Negotiation not assessed</td>
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<td>Domain D - Personal Competencies Critical Thinking assessed</td>
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<td>Integrity and Work Ethics assessed</td>
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<td></td>
<td></td>
<td>Self-direction and Self-management assessed</td>
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<tr>
<td>151-0601-00L</td>
<td>Theory of Robotics and Mechatronics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>P. Korba, S. Stoeter</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
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<tr>
<td>Objective</td>
<td>Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
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<tr>
<td>Content</td>
<td>An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
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<tr>
<td>Lecture notes</td>
<td>available.</td>
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<tr>
<td>151-0905-00L</td>
<td>Medical Technology Innovation - From Concept to Clinics</td>
<td>W</td>
<td>4</td>
<td>3P</td>
<td>I. Herrmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Project-oriented learning on how to develop technological solutions to address unmet clinical needs.</td>
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</tbody>
</table>
Objective

After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

Literature

will be available on the moodle.

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving assessed

Domain C - Social Competencies

Communication assessed

Cooperation and Teamwork assessed

Customer Orientation assessed

Leadership and Responsibility assessed

Self-presentation and Social Influence assessed

Sensitivity to Diversity assessed

Domain D - Personal Competencies

Adaptability and Flexibility assessed

Creative Thinking assessed

Critical Thinking assessed

Integrity and Work Ethics assessed

Self-awareness and Self-reflection assessed

Self-direction and Self-management assessed

227-1033-00L Neuromorphic Engineering I

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots.

Preference is given to students that require this class as part of their major.

Information for UZH students:

Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree/courses/special-students/special-students-university-of-zurich.html

Abstract

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective

Understanding of the characteristics of neuromorphic circuit elements.

Content

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature

S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice

Particular: The course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

227-0166-00L Analog Integrated Circuits

Abstract

This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

Objective

Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content

Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes

Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature


227-0447-00L Image Analysis and Computer Vision

Abstract

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Course material Script, computer demonstrations, exercises and problem solutions

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password etc.

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

The course language is English.
Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. This course will bring together engineering students from ETH Zurich and medical students from the University of Zurich to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become the most evident during actual collaborative work, the course is based on a current project in physiology research that combines medicine and engineering. For the engineering students, the specific aims of the course are to:

- Acquire a working understanding of the anatomy and physiology of the investigated system;
- Identify the engineering challenges in the project and communicate them to the medical students;
- Develop and implement, together with the medical students, solution strategies for the identified challenges;
- Present the found solutions to a cross-disciplinary audience.

After a general introduction to interdisciplinary communication and detailed background on the collaborative project, the engineering students will team up with medical students to find solutions to a biomedical challenge. In the process, they will be supervised both by lecturers from ETH Zurich and the University of Zurich, receiving coaching customized to the project. The course will end with each team presenting their solution to a cross-disciplinary audience.

Handouts and relevant literature will be provided.

IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Theory and corresponding exercises are merged together during the classes.

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!
Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main Frontiers in Nanotechnology

The objectives of this course are:

Concepts and Theories

Communication

Physical Modelling and Simulation

This seminar deals with the development of clinically relevant computational tools and/or their application to psychology and psychosomatics. It is complementary to the annual Computational Psychiatry Course and serves to build bridges between computational scientists and clinicians. It is designed to foster in-depth exchange, with ample time for discussion.

Understanding strengths and weaknesses of current trends in the development of clinically relevant computational tools and their application to problems in psychology and psychosomatics.

This seminar deals with the development of computational tools (e.g. generative models, machine learning) and/or their application to psychology and psychosomatics. The seminar includes (i) presentations by computational scientists and clinicians, (ii) group discussion with focus on methodology and clinical utility, (iii) self-study based on literature provided by presenters.

Literature for additional self-study of the topics presented in this seminar will be provided by the presenters and will be available online at

Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Autumn Semester 2021
Page 336 of 2152
Objective

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes

All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>W</th>
<th>credits</th>
<th>E</th>
<th>Lecturer</th>
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<tbody>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Riener, O. Lambery</td>
</tr>
</tbody>
</table>

Abstract

Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective

Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Content

Introduction, problem definition, overview
- Rehabilitation of visual function
  - Anatomy and physiology of the visual sense
  - Technical aids (glasses, sensor substitution)
  - Retina and cortex implants
  Rehabilitation of hearing function
  - Anatomy and physiology of the auditory sense
  - Hearing aids
  - Cochlea Implants
  Rehabilitation and use of kinesthetic and tactile function
  - Anatomy and physiology of the kinesthetic and tactile sense
  - Tactile/haptic displays for motion therapy (incl. electrical stimulation)
  - Role of displays in motor learning
  Rehabilitation of vestibular function
  - Anatomy and physiology of the vestibular sense
  - Rehabilitation strategies and devices (e.g. BrainPort)
  Rehabilitation of vegetative Functions
  - Cardiac Pacemaker
  - Phrenic stimulation, artificial breathing aids
  - Bladder stimulation, artificial sphincter
  Brain stimulation and recording
  - Deep brain stimulation for patients with Parkinson, epilepsy, depression
  - Brain-Computer Interfaces
Literature

Introductory Books:


Selected Journal Articles and Web Links:


Prerequisites / notice

- Students of higher semesters and PhD students of
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

376-1351-00L Micro/Nanotechnology and Microfluidics for Biomedical Applications

W 2 credits 2V E. Delamarche

Abstract

This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

Objective

The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.
Content

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-uL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

Objective

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

Content

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   Basic principles of conventional lithography of rigid materials, 'soft' lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small Volume Molecular Detection
   Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
    Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Prerequisites / notice

The nanotech center and labs visit at IBM would be mandatory, as well as attending the student project presentations.

Lecture notes

Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

Literature

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

Taught competencies

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

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

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed

529-0837-01L Biomicrofluidic Engineering
Number of participants limited to 25.

W 6 credits
3G A. de Mello
## Biology Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
<tr>
<td>227-0945-00L</td>
<td>Cell and Molecular Biology for Engineers I</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>C. Frei</td>
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</tbody>
</table>

### Abstract
- Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

### Objective
- Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

### Content
- 1. Insight Into The Mammalian Cell Cycle. Cycling. The Balance Between Proliferation and Cancer - Implications For Biopharmaceutical Manufacturing.
- 2. The Licence To Kill. Apoptosis Regulatory Networks - Engineering of Survival Pathways To Increase Robustness of Production Cell Lines.

### Literature
- Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
- Faller A., Schuenke M. The Human Body; Thieme 2004
- Netter F. Atlas of human anatomy; Elsevier 2014

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

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### Biological Methods for Engineers (Basic Lab) ■

#### Number of participants limited to 10.

#### Abstract
- The course during 7 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

#### Objective
- The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

#### Content
- The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.
Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

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

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

### Bioimaging
### Track Core Courses

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
227-0385-10L | Biomedical Imaging | W | 6 credits | 5G | S. Kozerke, K. P. Prüssmann

**Abstract**
Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Objective**
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Content**
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Lecture notes**
Lecture notes and handouts

**Literature**
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Prerequisites / notice**
Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

### Biomedical Engineering

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
227-0386-00L | Biomedical Engineering | W | 4 credits | 3G | J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong

**Abstract**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Objective**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

**Content**

**Lecture notes**
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

**Literature**
https://lib.ethz.ch/education/biomedical-engineering.html

### Image Analysis and Computer Vision

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
227-0447-00L | Image Analysis and Computer Vision | W | 6 credits | 3V+1U | L. Van Gool, E. Konukoglu, F. Yu

**Abstract**

**Objective**
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

227-0965-00L Micro and Nano-Tomography of Biological Tissues
W 4 credits 3G M. Stamparoni, F. Marone Welford

Abstract
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

Objective
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Content
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The course includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

Lecture notes
Will be indicated during the lecture.

Literature
Available online

Software
Moodle

Lecture notes
Supplementary material will be uploaded in Moodle.

Content
- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Number Title Type ECTS Hours Lecturers
227-0311-00L Qubits, Electrons, Photons W 6 credits 3V+2U T. Zambelli

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Content
Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

Literature
- Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

- (as rigorous and profound presentation of the mathematical framework) G. Dell’Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2015, Springer
- (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.
The lecture slides will be provided as a PDF after each lecture.

### Domain A - Subject-specific Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Taught</th>
<th>Notice</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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### Domain B - Method-specific Competencies

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</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
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</tr>
<tr>
<td>Media and Digital Technologies</td>
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<tr>
<td>Problem-solving</td>
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<tr>
<td>Project Management</td>
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### Domain C - Social Competencies

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<tbody>
<tr>
<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<tr>
<td>Sensitivity to Diversity</td>
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<tr>
<td>Negotiation</td>
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### Domain D - Personal Competencies

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<tbody>
<tr>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-direction and Self-management</td>
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### 227-0421-00L Deep Learning in Artificial and Biological Neuronal Networks

**Abstract**

Deep-Learning (DL) a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

### Objective

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g., simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

### Content

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al., 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

### Lecture notes

The lecture slides will be provided as a PDF after each lecture.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1. The number of participants is limited to 120 students (MSc and PhDs).
2. Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

### 227-0967-00L Computational Neuroimaging Clinic

**Prerequisite**: Successful completion of course "Methods & Models for fMRI Data Analysis", "Translational Neuromodeling" or "Computational Psychiatry"

**Abstract**

This seminar teaches problem solving skills for computational neuroimaging, based on joint analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

**Objective**

1. Consolidation of theoretical knowledge (obtained in the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuromodeling', 'Computational Psychiatry') in a practical setting.
2. Acquisition of practical problem solving strategies for computational modeling of neuroimaging data.

**Content**

This seminar teaches problem solving skills for computational neuroimaging, based on joint analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.
K. Stephan, M. Cook, B. Grewe, T. Delbrück

This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in understanding computation by neurons and neuronal circuits. One of the great challenges of science is to understand how the brain processes information and learns from experience. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the fundamental concepts of computation, learning, and decision-making. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

**Methods & Models for fMRI Data Analysis**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>227-0969-00L</td>
<td>Computational Psychiatry</td>
<td>3</td>
<td>W</td>
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<tr>
<td>227-0971-00L</td>
<td>Neuromorphic Engineering I</td>
<td>6</td>
<td>W</td>
<td>2V+3U</td>
</tr>
</tbody>
</table>

**Objective**

To provide in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), including preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Methods & Models for fMRI Data Analysis**

<table>
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<tbody>
<tr>
<td>227-0969-00L</td>
<td>Methods &amp; Models for fMRI Data Analysis</td>
<td>6</td>
<td>W</td>
<td>4V</td>
</tr>
</tbody>
</table>

**Abstract**

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Objective**

To provide in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Neuromorphic Engineering I**

<table>
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<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>6</td>
<td>W</td>
<td>2V+3U</td>
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</table>

**Abstract**

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

**Objective**

Understanding the characteristics of neuromorphic circuit elements.

**Content**

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

**Methods & Models for fMRI Data Analysis**

<table>
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<td>Methods &amp; Models for fMRI Data Analysis</td>
<td>6</td>
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**Abstract**

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Objective**

To provide in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Neuromorphic Engineering I**

<table>
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<td>Neuromorphic Engineering I</td>
<td>6</td>
<td>W</td>
<td>2V+3U</td>
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</table>

**Abstract**

This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

**Objective**

Understanding the characteristics of neuromorphic circuit elements.

**Content**

Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

**Methods & Models for fMRI Data Analysis**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
</tr>
</thead>
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<tr>
<td>227-0969-00L</td>
<td>Methods &amp; Models for fMRI Data Analysis</td>
<td>6</td>
<td>W</td>
<td>4V</td>
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</tbody>
</table>

**Abstract**

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Objective**

To provide in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Introduction to Neuroinformatics**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
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</thead>
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<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>6</td>
<td>W</td>
<td>2V+1U+1A</td>
</tr>
</tbody>
</table>

**Abstract**

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

**Objective**

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, math, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enforcements and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.
The course provides an introduction to digital image analysis in modern flow diagnostics. Different techniques which are discussed include Quantitative Flow Visualization, Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of H-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

**227-2037-00L**

**Physical Modelling and Simulation**

**W** 6 credits 4G  J. Smajic

**Abstract**

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

**Objective**

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

**Content**

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of H-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

**151-0105-00L**

**Quantitative Flow Visualization**

**W** 4 credits 3G  T. Rösgen

**Abstract**

The course provides an introduction to digital image analysis in modern flow diagnostics. Different techniques which are discussed include image velocimetry, laser induced fluorescence, liquid crystal thermography and interferometry. The physical foundations and measurement configurations are explained. Image analysis algorithms are presented in detail and programmed during the exercises.

**Objective**

Understanding of hardware and software requirements and solutions. Development of basic programming skills for (generic) imaging applications.

**Content**

Fundamentals of optics, flow visualization and electronic image acquisition. Frequently used image processing techniques (filtering, correlation processing, FFTs, color space transforms). Image Velocimetry (tracking, pattern matching, Doppler imaging). Surface pressure and temperature measurements (fluorescent paints, liquid crystal imaging, infrared thermography). Laser induced fluorescence. (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping. Wall shear and heat transfer measurements. Pattern recognition and feature extraction, proper orthogonal decomposition.

**Lecture notes**

Handouts will be made available.

**Prerequisites / notice**

Prerequisites: Fluidodynamics I, Numerical Mathematics, programming skills. Language: German on request.

**151-0605-00L**

**Nanosystems**

**W** 4 credits 4G  A. Stemmer

**Abstract**

From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures. Special emphasis on the emerging field of molecular electronic devices.

**Objective**

Familiarize students with basic science and engineering principles governing the nano domain.

**Content**

The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected. Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum

From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale

Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures.

**Literature**

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein

**Physics in Medical Research: From Atoms to Cells**

This course covers some of the fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

**Computer Graphics**

This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

**Biostatistics**

This course covers some of the fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

**Prerequisites / notice**

Lectures and Mini-Review presentations: Thursday 10-13

Homework: Mini-Review
(compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

252-0543-01L **Computer Graphics**

W 8 credits 3V+2U+2A

Does not take place this semester.

**Abstract**

This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.

**Objective**

At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students’ curiosity to explore the field of computer graphics in subsequent courses or on their own.

**Content**

This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

**Lecture notes**

Books:
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Physically Based Rendering: From Theory to Implementation

**Literature**

- Know the commonly used methods in biostatistics
- Perform simple data analysis with R
- Understand measurement of agreement, causality versus association.

**Prerequisites / notice**

Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, Visual

Computing course recommended.

The programming assignments will be in C++. This will not be taught in the class.

402-0674-00L **Physics in Medical Research: From Atoms to Cells**

W 6 credits 2V+1U  B. K. R. Müller

**Abstract**

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

**Objective**

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopolies.

465-0953-00L **Biostatistics**

W 4 credits 2V+1U

Does not take place this semester.

**Abstract**

The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association.

**Objective**

- Know the commonly used methods in biostatistics
- Perform simple data analysis with R

227-0976-00L **Computational Psychiatry & Computational Psychosomatics**

W 2 credits 4S  K. Stephan

**Number of participants limited to 24.**

Information for UZH students:
Enrolment to this course unit only possible at ETH Zurich. No enrolment to module BMT20002.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-
courses/special-
students/special-students-university-of-zurich.html

Abstract
This seminar deals with the development of clinically relevant computational tools and/or their application to psychiatry and
psychosomatics. It is complementary to the annual Computational Psychiatry Course and serves to build bridges between computational
scientists and clinicians. It is designed to foster in-depth exchange, with ample time for discussion.

Objective
Understanding strengths and weaknesses of current trends in the development of clinically relevant computational tools and their
application to problems in psychiatry and psychosomatics.

Content
This seminar deals with the development of computational tools (e.g. generative models, machine learning) and/or their application to
psychiatry and psychosomatics. The seminar includes (i) presentations by computational scientists and clinicians, (ii) group discussion with
focus on methodology and clinical utility, (iii) self-study based on literature provided by presenters.

Literature
For additional self-study of the topics presented in this seminar will be provided by the presenters and will be available online at
https://www.tnu.ethz.ch/en/teaching

Prerequisites / notice
Participants are expected to be familiar with general principles of statistics (including Bayesian statistics) and have successfully completed
the course “Computational Psychiatry” (Course number 227-0971-00L).

★★★★ Biology Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers an introduction into the structure and function of the human body, and how these are interlinked with one another. Focusing on physiology, the visualization of anatomy is supported by 3D-animation, Computed Tomography and Magnetic Resonance imaging.</td>
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<tr>
<td>Objective</td>
<td>To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.</td>
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</tr>
</tbody>
</table>
| Content        | - The Human Body: nomenclature, orientations, tissues  
- Musculoskeletal system, Muscle contraction  
- Blood vessels, Heart, Circulation  
- Blood, Immune system  
- Respiratory system  
- Acid-Base-Homeostasis |
| Literature     | Lecture notes and handouts  
Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008  
Faller A., Schuenke M. The Human Body; Thieme 2004  
Netter F. Atlas of human anatomy; Elsevier 2014 |
| Taught competencies | Domain A - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies  
Domain B - Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving  
Domain D - Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management |
| Notice         | Scripts of all lectures will be available. |

| 227-0945-00L   | Cell and Molecular Biology for Engineers I                             | W    | 3    | 2G    | C. Frei   |
| Abstract       | This course is part I of a two-semester course.  
The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology. |
| Objective      | After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested. |
| Content        | Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.  
In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II).  
For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication.  
These written documents will be graded and count as 40% for the final grade. |
| Literature     | Lecture notes and handouts  
| Taught competencies | Domain A - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies  
Domain B - Method-specific Competencies: Analytical Competencies, Decision-making, Media and Digital Technologies, Problem-solving  
Domain D - Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-awareness and Self-reflection, Self-direction and Self-management |
| Notice         | Scripts of all lectures will be available. |

| 227-0949-00L   | Biological Methods for Engineers (Basic Lab) ■                        | W    | 3    | 5P    | C. Frei   |
| Abstract       | The course during 7 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory. |
| Objective      | The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology. |
| Content        | The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology. |
| Prerequisites / notice | Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority. |
Taught competencies

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

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

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

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

Biomechanics

Track Core Courses

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüsmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.</td>
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<tr>
<td>Objective</td>
<td>To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.</td>
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<tr>
<td>Content</td>
<td>- X-ray imaging</td>
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<td></td>
<td>- Computed tomography</td>
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<td></td>
<td>- Single photon emission tomography</td>
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<td></td>
<td>- Positron emission tomography</td>
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<td></td>
<td>- Magnetic resonance imaging</td>
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<tr>
<td></td>
<td>- Ultrasound/Doppler imaging</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes and handouts</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming</td>
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<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.</td>
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<tr>
<td>Objective</td>
<td>Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.</td>
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<tr>
<td>Lecture notes</td>
<td>Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino</td>
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<td>AND</td>
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<td><a href="https://lbb.ethz.ch/education/biomedical-engineering.html">https://lbb.ethz.ch/education/biomedical-engineering.html</a></td>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W</td>
<td>6</td>
<td>3V+1U</td>
<td>L. Van Gool, E. Konukoglu, F. Yu</td>
</tr>
<tr>
<td>Objective</td>
<td>Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.</td>
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</tbody>
</table>
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but other examples of image processing using deep neural nets are given.

**Course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling.**

### Micro and Nano-Tomography of Biological Tissues

**W.** X. Welford, M. Stampanoni, F. Marone Welford

The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**

- Introduction to the basic concepts of X-ray tomographic imaging. Image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications

**Content**

Synchrontron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**

Available online

**Literature**

Will be indicated during the lecture.

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### Multiscale Bone Mechanics

**W.** C. List, P. Schütz

Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine.

**Objective**

1. Understanding and practical implementation of biosignal processes methods for imaging
2. Understanding of imaging techniques including radiographic imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging
3. Knowledge of computing, programming, modelling and simulation fundamentals
4. Computational and systems thinking as well as scripting and programming skills
5. Understanding and practical implementation of emerging computational methods and their application in medicine including artificial intelligence, deep learning, big data, and complexity
6. Understanding of the emerging concept of personalised and in silico medicine
7. Encouragement of critical thinking and creating an environment for independent and self-directed studying

**Content**

Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine. For the imaging portion of the course, biosignal processing, radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging are covered. For the computing portion of the course, computing, programming, and modelling and simulation fundamentals are covered as well as their application in artificial intelligence and deep learning; complexity and systems medicine; big data and personalised medicine; and computational physiology in and silico medicine.

The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup: in the first part (TORQUEs: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lectureads may prepare additional teaching material to answer the posted questions (Q&A). Following the Q&A, the students will form small groups to acquire additional knowledge using online, python-based activities via JupyterHub or additionally distributed material and discuss their findings in teams. Learning outcomes will be reinforced with weekly Moodle assignments, to be completed during the flipped classroom portion.

**Lecture notes**

Stored on Moodle

**Prerequisites / notice**

Lectures will be given in English.
Continuum Mechanics I

The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscous elasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
Basic theories for solving continuum mechanics problems of engineering applications, with particular attention to material models.

Content
Anisotropic elasticity, Linear elastic and linear viscous material behavior, Viscoelasticity, Micro-macro modelling, Laminate theory, Plasticity, Viscoplasticity, Examples of engineering applications, Comparison with experiments.

Lecture notes
yes

Theory of Robotics and Mechatronics

This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Objective
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Content
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Lecture notes
available.

Microrobotics

Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

Nanosystems

From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures. Special emphasis on the emerging field of molecular electronic devices.

Objective
Familiarize students with basic science and engineering principles governing the nano domain.
The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

Self-assembly and directed assembly of 2D and 3D structures.


Course format:
Lectures and Mini-Review presentations: Thursday 10-13
Homework: Mini-Review
(compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

151-0905-00L Medical Technology Innovation - From Concept to Clinics
4 credits
W 4 credits 3P I. Herrmann

Abstract
Project-oriented learning on how to develop technological solutions to address unmet clinical needs.

After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role. Course format will be available on the moodle.

Prerequisites / notice

Homework: Mini-Review
(compulsory continuous performance assessment)

4 credits
W 4 credits 3P I. Herrmann

Learning outcomes:
- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Communication
  - Leadership and Responsibility
  - Sensitivity to Diversity
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

376-1103-00L Frontiers in Nanotechnology
4 credits
W 4 credits 4V V. Vogel, further lecturers

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers. Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies. The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>3</td>
<td>S</td>
<td>R. Rien, O. Lambercy</td>
</tr>
</tbody>
</table>

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Content
- Introduction, problem definition, overview
- Rehabilitation of visual function
  - Anatomy and physiology of the visual sense
  - Technical aids (glasses, sensor substitution)
  - Retina and cortex implants
- Rehabilitation of hearing function
  - Anatomy and physiology of the auditory sense
  - Hearing aids
  - Cochlea Implants
- Rehabilitation and use of kinesthetic and tactile function
  - Anatomy and physiology of the kinesthetic and tactile sense
  - Tactile/haptic displays for motion therapy (incl. electrical stimulation)
  - Role of displays in motor learning
- Rehabilitation of vestibular function
  - Anatomy and physiology of the vestibular sense
  - Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
  - Cardiac Pacemaker
  - Phrenic stimulation, artificial breathing aids
  - Bladder stimulation, artificial sphincter
  - Brain stimulation and recording
  - Deep brain stimulation for patients with Parkinson, epilepsy, depression
  - Brain-Computer Interfaces
Handouts are deposited online (moodle).

Biocompatible Materials

The course covers the following topics:

K. Maniura

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Introduction into different material classes in use for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Integrating academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Handouts are deposited online (moodle).
Handouts and references therein.

376-1351-00L Micro/Nanotechnology and Microfluidics for Biomedical Applications

**Abstract**
This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and how they can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disk technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

**Objective**

The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

**Content**

Mostly formal lectures (2 x 45 min), with a 2 hour visit of the Binng and Rohrer Nanotechnology Center (Rueschikon) and introduction to cleanroom and micro/nanotechnology instruments, last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 10 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronic industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, micromirrors and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- hobby electronics, making a device for 10$ and controlling it using a smartphone.

**Prerequisites / notice**
The nanotech center and labs visit at IBM would be mandatory, as well as attending the student project presentations.

376-1720-00L Application of MATLAB in the Human Movement Sciences

**Abstract**
Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).

**Objective**
Students will acquire the ability to independently load, plot and process kinematic, kinetic and electromyographical data using the MATLAB computing environment.

**Content**
Drawbacks of Excel; Possibilities in MATLAB; Import of several data formats; Plot of one and more signals; Removing of an offset and filtering of data based on self-written functions; Normalisation and parametrisation of data; Reliability; Interpolation, Differentiation and Integration in MATLAB.

**Literature**
During the lecture, several electronically available MATLAB introductions are indicated. Course-specific scripts will be provided by the lecturer.

**Prerequisites / notice**
A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

376-1974-00L Colloquium in Biomechanics

**Abstract**
Current topics in biomechanics presented by speakers from academia and industry.

**Objective**
Getting insight into actual areas and problems of biomechanics.

376-2017-00L Biomechanics of Sports Injuries and Rehabilitation

**Abstract**
This lecture introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.

**Objective**
Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

**Content**
This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

**Lecture notes**
Handouts will be made available.

**Literature**

**Prerequisites / notice**
A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

402-0674-00L Physics in Medical Research: From Atoms to Cells

**Abstract**
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epithelial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultraviolet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X-rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

465-0953-00L Biostatistics W 4 credits 2V+1U

Abstract
The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics, testing hypotheses, confidence intervals, correlation, simple and multiple linear regression, classification and prediction, diagnostic tests, measurement of agreement, causality versus association.

Objective
- know the commonly used methods in biostatistics
- perform simple data analysis with R

 Faker A., Schuenke M. The Human Body; Thieme 2004
Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
Netter F. Atlas of human anatomy; Elsevier 2014

Biology Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers an introduction into the structure and function of the human body, and how these are interlinked with one another. Focusing on physiology, the visualization of anatomy is supported by 3D-animation, Computed Tomography and Magnetic Resonance imaging.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Content | - The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis |
| Literature | Lecture notes and handouts |
| Literature | Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
Faller A., Schuenke M. The Human Body; Thieme 2004
Netter F. Atlas of human anatomy; Elsevier 2014 |
| 227-0945-00L | Cell and Molecular Biology for Engineers I | W    | 3 credits | 2G    | C. Frei   |
| Abstract | This course is part I of a two-semester course. The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology. |
| Objective | After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested. |
| Content | Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells. |
| Literature | Scripts of all lectures will be available. |
The course during 7 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

### Taught competencies

#### Domain A - Subject-specific Competencies
- **Concepts and Theories**: assessed
- **Techniques and Technologies**: assessed

#### Domain B - Method-specific Competencies
- **Analytical Competencies**: not assessed
- **Decision-making**: assessed
- **Media and Digital Technologies**: not assessed
- **Problem-solving**: assessed
- **Project Management**: not assessed

#### Domain C - Social Competencies
- **Communication**: assessed
- **Cooperation and Teamwork**: assessed
- **Customer Orientation**: not assessed
- **Leadership and Responsibility**: not assessed
- **Self-presentation and Social Influence**: not assessed
- **Sensitivity to Diversity**: not assessed
- **Negotiation**: not assessed

#### Domain D - Personal Competencies
- **Adaptability and Flexibility**: assessed
- **Creative Thinking**: assessed
- **Critical Thinking**: assessed
- **Integrity and Work Ethics**: not assessed
- **Self-awareness and Self-reflection**: not assessed
- **Self-direction and Self-management**: not assessed

### Biological Methods for Engineers (Basic Lab)

**Number of participants limited to 10.**

**Abstract**

The course during 7 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

**Objective**

The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Enrollment is limited and students from the Master's programme in Biomedical Engineering (BME) have priority.

**Taught competencies**

#### Domain A - Subject-specific Competencies
- **Concepts and Theories**: assessed
- **Techniques and Technologies**: assessed

#### Domain B - Method-specific Competencies
- **Analytical Competencies**: not assessed
- **Decision-making**: assessed
- **Media and Digital Technologies**: not assessed
- **Problem-solving**: assessed
- **Project Management**: assessed

#### Domain C - Social Competencies
- **Communication**: assessed
- **Cooperation and Teamwork**: assessed
- **Customer Orientation**: not assessed
- **Leadership and Responsibility**: not assessed
- **Self-presentation and Social Influence**: not assessed
- **Sensitivity to Diversity**: not assessed
- **Negotiation**: not assessed

#### Domain D - Personal Competencies
- **Adaptability and Flexibility**: not assessed
- **Creative Thinking**: assessed
- **Critical Thinking**: assessed
- **Integrity and Work Ethics**: not assessed
- **Self-awareness and Self-reflection**: not assessed
- **Self-direction and Self-management**: not assessed

### Medical Physics

#### Track Core Courses

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0311-00L</td>
<td>Qubits, Electrons, Photons</td>
<td>W</td>
<td>6 credits</td>
<td>3V+2U</td>
<td>T. Zambelli</td>
</tr>
</tbody>
</table>

**Abstract**

In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

**Objective**

Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

**Content**

- Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
- Postulates of QM: Hilbert Spaces and Operators
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
- Spin: Qubits, Bloch Equations, and NMR
- Entanglement
- Symmetries and Corresponding Operators
- Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
- Harmonic Oscillator: Creation and Annihilation Operators
- Identical Particles: Bosons and Fermions
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener
Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques.

To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Prerequisites**: Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

By the end of this course the participants will be able to:

- interpret the 5 Rs of radiation oncology in the context of the hallmarks of cancer
- understand factors which underpin the differing radiosensitivities of different tumors
- follow rational strategies for combined treatment modalities of ionizing radiation with targeted agents
- understand differences in the radiation response of normal tissue versus tumor tissue
- understand different treatment responses of the tumor and the normal tissue to differential clinical-related parameters of radiotherapy (dose rate, LET etc.).

**Lecture notes and handouts**: Lecture notes and handouts will be provided.

**Prerequisites / notice**: Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming.

**Literature / notice**: Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Supplementary material will be uploaded in Moodle.**

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**227-0385-10L Biomedical Imaging**

- **Abstract**
  - Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

- **Objective**
  - To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

- **Content**
  - X-ray imaging
  - Computed tomography
  - Single photon emission tomography
  - Positron emission tomography
  - Magnetic resonance imaging
  - Ultrasound/Doppler imaging

- **Lecture notes**
  - Lecture notes and handouts

- **Literature**
  - Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**227-0943-00L Radiobiology**

- **Abstract**
  - The purpose of this course is to impart basic knowledge in radiobiology in order to handle ionizing radiation and to provide a basis for predicting the radiation risk.

- **Objective**
  - By the end of this course the participants will be able to:
    a) interpret the 5 Rs of radiation oncology in the context of the hallmarks of cancer
    b) understand factors which underpin the differing radiosensitivities of different tumors
    c) follow rational strategies for combined treatment modalities of ionizing radiation with targeted agents
    d) understand differences in the radiation response of normal tissue versus tumor tissue
    e) understand different treatment responses of the tumor and the normal tissue to differential clinical-related parameters of radiotherapy (dose rate, LET etc.).

- **Content**
  - Einführung in die Strahlenbiologie ionisierender Strahlen: Allgemeine Grundlagen und Begriffsbestimmungen; Mechanismen der biologischen Strahlenwirkung; Strahlenwirkung auf Zellen. Gewebe und Organe; Modifikation der biologischen Strahlenwirkung; Strahlencytogenetik: Chromosomenveränderungen, DNA-Defekte, Reparaturprozesse; Molekulare Strahlenbiologie: Bedeutung inter- und intrazellulärer Signalübermittlungsprozesse, Apoptose, Zellzyklus-Checkpoints; Strahlenrisiko: Strahlensyndrome, Krebsinduktion, Mutationsauslösung, pränatale Strahlenwirkung; Strahlenbiologische Grundlagen des Strahlenschutzes; Nutzen-Risiko-Abwägungen bei der medizinischen Strahlentherapie; Prädiktive strahlenbiologische Methoden zur Optimierung der therapeutischen Strahlentherapie.

- **Lecture notes**
  - Beilagen mit zusammenfassenden Texten, Tabellen, Bild- und Grafikdarstellungen werden abgegeben
**Literature**

- Literaturliste wird abgegeben.
- Basic Clinical Radiobiology, edited by Joiner, van der Kogel, 2018

**Prerequisites / notice**

The former number of this course unit is 465-0951-00L.

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### Recommended Elective Courses

These courses are particularly recommended for the Medical Physics track. Please consult your track advisor if you wish to select other subjects.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0341-00L</td>
<td>Medical Physics I</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Manser</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

**Objective**

Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefit of patients and the society.

**Content**

The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the exercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

**Lecture notes**

A script will be provided.

- For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

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### Autumn Semester 2021

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<th>Number</th>
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<tr>
<td>402-0674-00L</td>
<td>Physics in Medical Research: From Atoms to Cells</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>B. K. R. Müller</td>
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</table>

**Abstract**

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

**Objective**

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact material data. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

**Prerequisites / notice**

- A script will be provided.

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### Autumn Semester 2021

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<th>Number</th>
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<tr>
<td>227-0941-00L</td>
<td>Physics and Mathematics of Radiotherapy Planning (University of Zurich)</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>University lecturers</td>
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</tbody>
</table>

**Abstract**

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: PHY471

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

**Objective**

This lecture will provide a detailed introduction to radiotherapy treatment planning. The course considers the physical interactions of radiation in tissue, the mathematical aspects of treatment planning and additional aspects of central importance for radiotherapy planning.

Students shall develop a thorough understanding of the foundations of radiotherapy from a physics and mathematics perspective, focusing on algorithmic components. After completing the course students should be able to implement the main components of a radiotherapy treatment planning system.
Radiography is one of the main treatment options against cancer. Today, more than 50% of cancer patients receive radiation as part of their treatment. Modern radiotherapy is a highly technology driven field.

Research and development in medical physics has improved the precision of radiotherapy substantially. Using intensity-modulated radiotherapy (IMRT), radiation can be delivered precisely to tumors while minimizing radiation exposure of healthy organs surrounding the tumor. Thereby, medical physics has provided radiation oncologists with new curative treatment approaches where previously only palliative treatments were possible. This lecture will provide a detailed introduction to radiotherapy treatment planning and will consists of three blocks:

1. The first part of the course considers the physical interactions of radiation in tissue. The physical interactions give rise to dose calculation algorithms, which are used to calculate the absorbed radiation dose based on a CT scan of the patient.

2. The second part considers the mathematical aspects of treatment planning. Mathematical optimization techniques are introduced, which are used in intensity-modulated radiotherapy to determine the external radiation fields that optimally irradiate the tumor while minimizing radiation dose to healthy organs.

3. The third part deals with additional aspects of central importance for radiotherapy planning. This includes biomedical imaging techniques for treatment planning and target delineation as well as image registration algorithms.

The lectures are followed by computational exercises where students implement the main components of a radiotherapy treatment planning systems in two dimensions in Matlab.

Prerequisites:
Basic programming skills in Matlab (or willingness to learn) are needed for the exercises. Basic knowledge of calculus is needed, approximately corresponding to the 3rd year of a bachelor degree in physics, mathematics, computer science, engineering or comparable discipline.

Other Elective Courses

These courses may be suitable for the Medical Physics track. Please consult your track advisor.

Biology Courses

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers an introduction into the structure and function of the human body, and how these are interlinked with one another. Focusing on physiology, the visualization of anatomy is supported by 3D-animation, Computed Tomography and Magnetic Resonance imaging.</td>
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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Welford</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<tr>
<td>Objective</td>
<td>Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allows quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.</td>
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<tr>
<td>Content</td>
<td>The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.</td>
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<tr>
<td>Lecture notes</td>
<td>Available online</td>
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<tr>
<td>Literature</td>
<td>Will be indicated during the lecture.</td>
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The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, cellular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology. After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested. Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication. These written documents will be graded and count as 40% for the final grade.

**Molecular Bioengineering**  

**Track Core Courses**  

During the Master programme, a minimum of 12 CP must be obtained from track core courses.

<table>
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<th>Number</th>
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<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4</td>
<td>4V</td>
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<tr>
<td></td>
<td>Abstract</td>
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</table>
|           | Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers. Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.
|           | The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries. Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.
|           | Content                      |      |      |       |
|           | Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.
|           | Lecture notes                |      |      |       |
|           | All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics. |      |      |       |
Introduction into molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes
Handouts are deposited online (moodle).

Literature

(available online via ETH library)

Handouts and references therin.

402-0674-00L

Abstract
Physics in Medical Research: From Atoms to Cells

Objective
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and anisotropies of biopsies.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

636-0108-00L

Abstract
Biological Engineering and Biotechnology

Objective
Biological and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Handout during the course.
### Lecturers
Main topics of the course include:

**Microrobotics**

Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

**Medical Technology Innovation - From Concept to Communication**

The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

**3P Concepts and Theories**

The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

**Adaptability and Flexibility**

After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

**Analytical Competencies**

Project-oriented learning on how to develop technological solutions to address unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. The lecture will be taught in English.

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### Recommended Elective Courses

*These courses are particularly recommended for the Molecular Bioengineering track. Please consult your track advisor if you wish to select other subjects.*

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson, N. Shamsudhin</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Main topics of the course include:</td>
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<td></td>
<td>- Scaling laws at micro/nano scales</td>
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<td>- Electrostatics</td>
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<td>- Electromagnetism</td>
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<td>- Low Reynolds number flows</td>
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<td>- Observation tools</td>
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<td>- Materials and fabrication methods</td>
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<td></td>
<td>- Applications of biomedical microrobots</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>The lecture will be taught in English.</td>
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| 151-0905-00L| Medical Technology Innovation - From Concept to Clinics | W    | 4   | 3P   | I. Herrmann |
| **Abstract**| Project-oriented learning on how to develop technological solutions to address unmet clinical needs. |
| **Objective**| After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role. |
| **Literature**| will be available on the moodle. |
| **Taught competencies**| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| | | Techniques and Technologies | assessed |
| | Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| | | Decision-making | assessed |
| | | Problem-solving | assessed |
| | | Project Management | assessed |
| | Domain C - Social Competencies | Communication | assessed |
| | | Cooperation and Teamwork | assessed |
| | | Customer Orientation | assessed |
| | | Leadership and Responsibility | assessed |
| | | Self-presentation and Social Influence | assessed |
| | | Sensitivity to Diversity | assessed |
| | | Negotiation | assessed |
| | Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| | | Creative Thinking | assessed |
| | | Critical Thinking | assessed |
| | | Integrity and Work Ethics | assessed |
| | | Self-awareness and Self-reflection | assessed |
| | | Self-direction and Self-management | assessed |

| 227-0311-00L| Qubits, Electrons, Photons | W    | 6    | 3V+2U | T. Zambelli |
| **Abstract**| In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis). Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics. |
| **Objective**| Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition! |
| **Content**| • Lagrangian and Hamiltonian: Symmetries and Poisson Brackets |
| | | • Postulates of QM: Hilbert Spaces and Operators |
| | | • Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator |
| | | • Spin: Qubits, Bloch Equations, and NMR |
| | | • Entanglement |
| | | • Symmetries and Corresponding Operators |
| | | • Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands |
| | | • Harmonic Oscillator: Creation and Annihilation Operators |
| | | • Identical Particles: Bosons and Fermions |
| | | • Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER |
| | | • Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener |
| **Lecture notes**| No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive! |

!!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!!


Supplementary material will be uploaded in Moodle.


The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in moodle!

**Domain A - Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management assessed

**Domain C - Social Competencies**
- Communication not assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity assessed
- Negotiation not assessed

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

### 227-0385-10L Biomedical Imaging

**Abstract**
Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

**Objective**
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Content**
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Lecture notes**
Lecture notes and handouts

**Literature**
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Prerequisites / notice**
Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

### 227-0386-00L Biomedical Engineering

**Abstract**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Objective**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

**Content**

**Lecture notes**
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

**AND**
https://lbb.ethz.ch/education/biomedical-engineering.html

---

Cross-disciplinary collaboration between engineers and medical doctors is indispensable for innovation in health care. This course will introduce the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

The course introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques are discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics. The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It brings together engineering students from ETH Zurich and medical students from the University of Zurich to experience the rewards and challenges of such interdisciplinary work in a project based learning environment.

### Content

**L1. Bioelectronics history, its applications and overview of the field**
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

**L2. Fundamentals of quantum and classical noise in measuring biological signals**

**L3. Biomeasurement techniques with photons**

**L4. Acoustics sensors**
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

**L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes**

**L6. Optical biosensors**
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

**L7. Basic notions of molecular adsorption and electron transfer**
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

**L8. Potentiometric sensors**
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

**L9. Amperometric sensors and bioelectric potentials**
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

**L10. Channels, amplification, signal gating, and patch clamp Y4**

**L11. Action potentials and impulse propagation**

**L12. Functional electric stimulation and recording**
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

**L13. Neural networks memory and learning**

### Literature

- Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)
- Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

### Prerequisites / notice

The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

### Objective

During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

### Objective

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

### Content

Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

### Lecture notes

Available online

### Literature

Will be indicated during the lecture.
Objective

The main goal of this course is to demonstrate the differences in communication between the fields of medicine and engineering. Since such differences become the most evident during actual collaborative work, the course is based on a current project in physiology research that combines medicine and engineering. For the engineering students, the specific aims of the course are to:

- Acquire a working understanding of the anatomy and physiology of the investigated system;
- Identify the engineering challenges in the project and communicate them to the medical students;
- Develop and implement, together with the medical students, solution strategies for the identified challenges;
- Present the found solutions to a cross-disciplinary audience.

Content

After a general introduction to interdisciplinary communication and detailed background on the collaborative project, the engineering students will team up with medical students to find solutions to a biomedical challenge. In the process, they will be supervised both by lecturers from ETH Zürich and the University of Zurich, receiving coaching customized to the project. The course will end with each team presenting their solution to a cross-disciplinary audience.

Lecture notes

Handouts and relevant literature will be provided.

Prerequisites / notice

IMPORTANT: Note that a special permission from the lecturers is required to register for this course. Contact the head lecturer to that end.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Analytical Competencies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Project Management</td>
<td>assessed</td>
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<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<td>Customer Orientation</td>
<td>assessed</td>
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</tbody>
</table>

327-0505-00L Surfaces, Interfaces and their Applications I

W 3 credits 2V+1U N. Spencer, M. P. Heuberger, L. Isa

Abstract

After being introduced to the physical/chemical principles and importance of surfaces and interfaces, the student is introduced to the most important techniques that can be used to characterize surfaces. Later, liquid interfaces are treated, followed by an introduction to the fields of tribology (friction, lubrication, and wear) and corrosion.

Objective

To gain an understanding of the physical and chemical principles, as well as the tools and applications of surface science, and to be able to choose appropriate surface-analytical approaches for solving problems.

Content

Introduction to Surface Science

Surface Forces (static and dynamic)

Adsorbates on Surfaces

Surface Thermodynamics and Kinetics

The Solid-Liquid Interface

Electron Spectroscopy

Vibrational Spectroscopy on Surfaces

Scanning Probe Microscopy

Introduction to Tribology

Introduction to Corrosion Science

Lecture notes

Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=14993

Literature

Script Download: https://moodle-app2.let.ethz.ch/course/view.php?id=14993


Prerequisites / notice

Chemistry:

General undergraduate chemistry

including basic chemical kinetics and thermodynamics

Physics:

General undergraduate physics

including basic theory of diffraction and basic knowledge of crystal structures

Taught competencies

<table>
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<td>Domain C - Social Competencies</td>
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<td>assessed</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<td></td>
<td>Customer Orientation</td>
<td>assessed</td>
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</tbody>
</table>

327-1101-00L Biominalization

W 2 credits 2V K.-H. Ernst

Abstract

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization. The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

Objective

Biominalization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / sintering / photosynthesis / calcite and aragonite / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

Content

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization
376-1622-00L  
**Practical Methods in Tissue Engineering**  
*W* 5 credits 4P  
M. Zenobi-Wong, S. J. Ferguson, S. Grad, S. Schürle-Finke  
Number of participants limited to 12  

**Abstract**  
The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.  

**Objective**  
Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In addition to practical lab work, the course will teach skills in data acquisition/analysis.  

**Prerequisites / notice**  
A Windows laptop (or Windows on Mac) is required for certain of the lab modules.

402-0341-00L  
**Medical Physics I**  
*W* 6 credits 2V+1U  
P. Manser  

**Abstract**  
Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiologically and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.  

**Objective**  
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society.  

**Content**  
The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the exercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy, and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.  

**Lecture notes**  
A script will be provided.  

**Prerequisites / notice**  
For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

529-0240-00L  
**Chemical Biology - Peptides**  
*W* 6 credits 3G  
H. Wennemers  

**Abstract**  
An advanced course on the synthesis, properties and function of peptides in chemistry and biology. Knowledge of the synthesis, properties and function of peptides in chemistry and biology.  

**Objective**  
Advanced peptide synthesis, conformations, properties and interaction, peptide-based medicines, peptide technologies, peptides in asymmetric catalysis.  

**Content**  
Citations from the original literature relevant to the individual lectures will be assigned weekly.  

**Literature**  

529-0615-01L  
**Biochemical and Polymer Reaction Engineering**  
*W* 6 credits 3G  
P. Arosio  

**Abstract**  

**Objective**  
The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.  

**Content**  
We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes. Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation modeling. Model and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.  

**Lecture notes**  
Scripts are available on the web page of the Arosio-group: http://www.arosigroup.ethz.ch/education.html  

**Literature**  

535-0423-00L  
**Drug Delivery and Drug Targeting**  
*W* 2 credits 1.5V  
J.-C. Leroux, A. Steinauer  

**Abstract**  
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.  

**Objective**  
The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the challenges and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.  

**Content**  
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.  

**Lecture notes**  
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.  

**Literature**  

Further references will be provided in the course.
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving

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

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

636-0507-00L Synthetic Biology II

W 8 credits 4A S. Panke, Y. Benenson, J. Stelling

Abstract
7 months biological design project, during which the students are required to give presentations on advanced topics in synthetic biology (specifically genetic circuit design) and then select their own biological system to design. The system is subsequently modeled, analyzed, and experimentally implemented. Results are presented at an international student competition at the MIT (Cambridge).

Objective
The students are supposed to acquire a deep understanding of the process of biological design including model representation of a biological system, its thorough analysis, and the subsequent experimental implementation of the system and the related problems.

Content
Presentations on advanced synthetic biology topics (eg genetic circuit design, adaptation of systems dynamics, analytical concepts, large scale de novo DNA synthesis), project selection, modeling of selected biological system, design space exploration, sensitivity analysis, conversion into DNA sequence, (DNA synthesis external) implementation and analysis of design, summary of results in form of scientific presentation and poster, presentation of results at the iGEM international student competition (www.igem.org).

Lecture notes
Handouts during course

Prerequisites / notice
The final presentation of the project is typically at the MIT (Cambridge, US). Other competing schools include regularly Imperial College, Cambridge University, Harvard University, UC Berkeley, Princeton University, CalTech, etc.

This project takes place between end of Spring Semester and beginning of Autumn Semester. Registration in April.

Please note that the number of ECTS credits and the actual work load are disconnected.

Other Elective Courses
These courses may be suitable for the Molecular Bioengineering track. Please consult your track advisor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0313-00L Microbiology (Part I)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>W.-D. Hardt, L. Eberl, J. Piel, M. Pilhofer</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
English

The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

Biology Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0399-10L Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wyss</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
This course offers an introduction into the structure and function of the human body, and how these are interlinked with one another. Focusing on physiology, the visualization of anatomy is supported by 3D-animation, Computed Tomography and Magnetic Resonance imaging.

Objective
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

Content
- The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

Lecture notes
Lecture notes and handouts

Literature
Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
Faller A., Schuenke M. The Human Body; Thieme 2004
Netter F. Atlas of human anatomy; Elsevier 2014

227-0945-00L Cell and Molecular Biology for Engineers I

W 3 credits 2G C. Frei

This course is part I of a two-semester course.
The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Objective
After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content
Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication. These written documents will be graded and count as 40% for the final grade.

Lecture notes
Scripts of all lectures will be available.

Literature

Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies not assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management not assessed

**Domain C - Social Competencies**
- Communication not assessed
- Cooperation and Teamwork assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed

227-0949-00L Biological Methods for Engineers (Basic Lab) W 3 credits 5P C. Frei

Number of participants limited to 10.

Abstract
The course during 7 afternoons (13h to 18h) covers basic laboratory skills and safety, cell culture, protein analysis, RNA/DNA Isolation and RT-PCR. Each topic will be introduced, followed by practical work at the bench. Presence during the course is mandatory.

Objective
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Content
The goal of this laboratory course is to give students practical exposure to basic techniques of cell and molecular biology.

Prerequisites / notice
Enrollment is limited and students from the Master’s programme in Biomedical Engineering (BME) have priority.

Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories assessed
- Techniques and Technologies assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management assessed

**Domain C - Social Competencies**
- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility not assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed

Projects and Laboratory Courses

Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0 credits</td>
<td>U. Koch</td>
<td></td>
</tr>
</tbody>
</table>

This strongly recommended prerequisite for Semester Projects and Master Theses at D-ITET (MSc BME, MSc EEIT, MSc EST).

Abstract
The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be thought on two afternoons. Some exercises will be built into the lecture.
Objective
Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content
* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).
* Topic 2: Power Point Presentations.
* Topic 3: Citation Rules and Citation Software.
* Topic 4: Guidelines for Research Integrity.

Literature
ETH "Citation Etiquette", see www.plagiate.ethz.ch.


Prerequisites / notice
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

227-1772-10L Semester Project 0 12 credits 20A Professors
Registration in mystudies required!

Abstract
The semester project is designed to train the students in solving specific biomedical engineering problems. This project uses the technical and social skills acquired during the master's program. The semester project is advised by a professor.

Objective
see above

227-1772-20L Semester Project 2 W 12 credits 20A Professors
Only for Programme Regulations 2020.
Registration in mystudies required!

Abstract
The semester project is designed to train the students in solving specific biomedical engineering problems. This project uses the technical and social skills acquired during the master's program. The semester project is advised by a professor.

Objective
see above

227-1750-00L Internship in Industry W 12 credits Professors
Only for Biomedical Engineering MSc (Programme Regulations 2020).

Abstract
The main objective of the 12-week internship is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Objective
see above

227-1760-00L Research Project (long) W 24 credits 40A Professors
Only for Biomedical Engineering MSc (Programme Regulations 2020).

Abstract
The aim of the long research project is to perform a larger (exploratory) scientific study or a larger development project in a team. The duration of this project is at least four months (full-time) and it is finished with a report and/or prototype.

Objective
see above

Master's Thesis

227-1101-00L How to Write Scientific Texts E- 0 credits U. Koch
Strongly recommended prerequisite for Semester Projects and Master Theses at D-ITET (MSc BME, MSc EEIT, MSc EST).

Abstract
The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be thought on two afternoons. Some exercises will be built into the lecture.

Objective
Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content
* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).
* Topic 2: Power Point Presentations.
* Topic 3: Citation Rules and Citation Software.
* Topic 4: Guidelines for Research Integrity.

Literature
ETH "Citation Etiquette", see www.plagiate.ethz.ch.


Prerequisites / notice
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

227-1700-00L Master's Thesis O 30 credits 40D Professors
Admission only if all the following apply:
a. bachelor program successful completed;
b. any additional requirements necessary to gain admission to the master program BME have been successfully completed;
c. both the semester project and (if applicable) the internship successfully completed.

Registration in myStudies required!
Abstract
The masters program culminates in a six months research project which addresses a scientific research question on one's chosen area of specialization. The masters thesis is supervised by a program-affiliated faculty member and the topic must be approved by the track advisor.

Objective
see above

> GESS Science in Perspective

see GESS Science in Perspective: Language Courses ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-ITET.

> Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0970-00L</td>
<td>Research Topics in Biomedical Engineering</td>
<td>Z</td>
<td>0 credits</td>
<td>1K</td>
<td>K. P. Prüssmann, S. Kozerke, M. Stampanoni, K. Stephan, J. Vörös</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
<td></td>
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</tbody>
</table>

Abstract
Current topics in Biomedical Engineering presented by speakers from academia and industry.

Objective
Getting insight into actual areas and problems of Biomedical Engineering an Health Care.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0980-00L</td>
<td>Seminar on Biomedical Magnetic Resonance</td>
<td>Z</td>
<td>0 credits</td>
<td>1S</td>
<td>K. P. Prüssmann, S. Kozerke, M. Weiger Senften</td>
</tr>
</tbody>
</table>

Abstract
Current developments and problems of magnetic resonance imaging (MRI)

Objective
Getting insight into advanced topics in magnetic resonance imaging

Biomedical Engineering Master - Key for Type

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

Key for Hours

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

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Biotechnology Master

► Master Studies (Programme Regulations 2021)

►► Core Courses

Students need to acquire a total of 6 ECTS in lectures in this category.
The list of core courses is a closed list, no other course can be added to this category.
Students need to pass both lectures offered in this category.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
This course provides an overview of modern concepts of bioengineering across different levels of complexity, from single molecules to systems, microscaled reactors to production environments, and across different fields of applications.

Objective
Students will be able to recognize major developments in bioengineering across different organisms and levels of complexity and be able to relate it to major technological and conceptual advances in the underlying sciences.

Content
Molecular and cellular engineering; Synthetic biology: Engineering strategies in biology; from single molecules to systems; downscaling bioengineering; Bioengineering in chemistry, pharmaceutical sciences, and diagnostics, personalized medicine.

Lecture notes
Handouts during class

Literature
Will be announced during the course

Taught competencies
Domain A - Subject-specific Competencies: Concepts and Theories assessed
Domain D - Personal Competencies: Critical Thinking assessed

►► Research Project and Industry Internship

Students can choose between Research Project OR Industry Internship. Duration: 12 weeks full-time min. Must be carried out in a different research group/company than the master’s thesis.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0805-00L</td>
<td>Research Project</td>
<td>W</td>
<td>16 credits</td>
<td>34A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student. Research Project duration: 12 weeks, completed with a written report.

Objective
Students get acquainted with scientific working methods and deepen their knowledge in a particular research area

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0806-00L</td>
<td>Industry Internship</td>
<td>W</td>
<td>16 credits</td>
<td>34A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
Industry internship of at least 12 weeks, completed with a written report.

Objective
Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the courses.

Prerequisites / notice
The students look for a placement themselves.

►► Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0900-10L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>44 credits</td>
<td>91D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is carried out under the supervision of a professor in a research group of the D-BSSE, usually at the D-BSSE. Students are free to choose the area.

Objective
In the Master thesis students prove their ability to independent, structured and scientific working.

► Master Studies (Programme Regulations 2017)

►► Core Courses

Students need to acquire a total of 8 ECTS in lectures in this category.
The list of core courses is a closed list, no other course can be added to this category.
Students need to pass both lectures offered in this category.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
This course provides an overview of modern concepts of bioengineering across different levels of complexity, from single molecules to systems, microscaled reactors to production environments, and across different fields of applications.
Objective: Students will be able to recognize major developments in bioengineering across different organisms and levels of complexity and be able to relate it to major technological and conceptual advances in the underlying sciences.

Content: Molecular and cellular engineering; Synthetic biology; Engineering strategies in biology; from single molecules to systems; downscaling bioengineering; Bioengineering in chemistry, pharmaceutical sciences, and diagnostics, personalized medicine.

Lecture notes: Handouts during class

Literature: Will be announced during the course

Taught competencies:
- Domain A - Subject-specific Competencies: Concepts and Theories, assessed
- Domain B - Critical Competencies: Techniques and Technologies, assessed
- Domain C - Personal Competencies: Critical Thinking, assessed

Research Projects and Internship

Students need to acquire a total of 20 ECTS in this category.

Either choose Research Project I (8 ECTS) and Research Project II (12 ECTS)

Or choose Research Project I (8 ECTS) and Industry Internship (12 ECTS)

Instead of Research Project I (8 ECTS) students may also choose Synthetic Biology II (8 ECTS)

Research Projects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0802-00L</td>
<td>Research Project I ■ Only for Biotechnologie Master BSc, Programme Regulations 2017.</td>
<td>O</td>
<td>8</td>
<td>23A</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student. Research Project I duration: 8 weeks</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Students get acquainted with scientific working methods and deepen their knowledge in a particular research area</td>
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</tbody>
</table>

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0803-00L</td>
<td>Research Project II ■ Only for Biotechnologie Master BSc, Programme Regulations 2017.</td>
<td>W</td>
<td>12</td>
<td>34A</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student. Research Project II duration: 12 weeks</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students get acquainted with scientific working methods and deepen their knowledge in a particular research area</td>
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</table>

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0507-00L</td>
<td>Synthetic Biology II Does not take place this semester. Students in the MSc Biotechnology (Programme Regulations 2017) may select Synthetic Biology II instead of the Research Project 1.</td>
<td>W</td>
<td>8</td>
<td>4A</td>
<td>Professors, Y. Benenson, J. Stelling</td>
</tr>
<tr>
<td>Abstract</td>
<td>7 months biological design project, during which the students are required to give presentations on advanced topics in synthetic biology (specifically genetic circuit design) and then select their own biological system to design. The system is subsequently modeled, analyzed, and experimentally implemented. Results are presented at an international student competition at the MIT (Cambridge).</td>
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<tr>
<td>Objective</td>
<td>The students are supposed to acquire a deep understanding of the process of biological design including model representation of a biological system, its thorough analysis, and the subsequent experimental implementation of the system and the related problems.</td>
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<tr>
<td>Content</td>
<td>Presentations on advanced synthetic biology topics (e.g., genetic circuit design, adaptation of systems dynamics, analytical concepts, large scale de novo DNA synthesis, project selection, modeling of selected biological system, design space exploration, sensitivity analysis, conversion into DNA sequence, (DNA synthesis external) implementation and analysis of design, summary of results in form of scientific presentation and poster, presentation of results at the iGEM international student competition (<a href="http://www.igem.org">www.igem.org</a>).</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts during course</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The final presentation of the project is typically at the MIT (Cambridge, US). Other competing schools include regularly Imperial College, Cambridge University, Harvard University, UC Berkeley, Princeton University, CalTech, etc. This project takes place between end of Spring Semester and beginning of Autumn Semester. Registration in April.</td>
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</tbody>
</table>

Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0804-00L</td>
<td>Industry Internship ■ Only for Biotechnologie Master BSc, Programme Regulations 2017.</td>
<td>W</td>
<td>12</td>
<td>34A</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>Industry internship of at least 12 weeks, completed with a written report.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the courses.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The students look for a placement themselves.</td>
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</tbody>
</table>

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0900-00L</td>
<td>Master's Thesis ■ In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is carried out under the supervision of a professor in a research group of the D-BSSE, usually at the D-BSSE. Students are free to choose the area.</td>
<td>O</td>
<td>40</td>
<td>91D</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>In the Master Thesis students prove their ability to independent, structured and scientific working.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>In the Master Thesis students prove their ability to independent, structured and scientific working.</td>
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</tbody>
</table>

Practical Training

All listed lab courses are mandatory.

For Students in Biotechnology Master, Programme Regulation 2021: 16 ECTS in this category are mandatory.

For Students in Biotechnology Master, Programme Regulation 2017: 14 ECTS in this category are mandatory.
Critical Thinking

This practical course is an introduction to microsystems technology and microfluidics for the life sciences. It includes basic concepts of:


Lab Course: Microsystems and Microfluidics in Biology

- T. Horn

Objective

- to understand the technical and physical principles of light microscopes and flow cytometers
- to have hands-on experience in the use of these technologies to analyze image real samples
- to be able to run a basic analysis of the data and images obtained with flow cytometers and microscopes
- to get introduced to liquid handling (pipetting) robotics and learn how to implement a basic workflow

Content

The practical course will have five units at 2 days each (total 10 days):

1. Flow Cytometry:
   a. Introduction to Flow Cytometry
   b. Practical demonstration on flow cytometry analyzers and flow cytometry cell sorters
   c. Flow cytometry sample preparation
   d. Learn how to use flow cytometry equipment to analyze and sort fluorescence-labeled cells
2. Light microscopy
   a. Learn how to build a microscope and understand the underlying physical principles
   b. Learn how to use a modern automated wide field fluorescence microscope
   c. Use this microscope to automatically acquire images of a cell culture assay to analyze the dose-dependent effect of a drug treatment
3. Image Analysis
   a. Introduction to the fundamentals of image analysis
   b. Learn the basics of the image analysis software Fiji/ImageJ
   c. Use Fiji/ImageJ to analyze the images acquired during the microscopy exercise
4. Laboratory Automation
   a. Introduction to the basics of automated liquid handling/ lab robotics
   b. See examples on using lab automation for plasmid library generation and cell cultivation
   c. Learn how to program and execute a basic pipetting workflow including liquid handling and labware transfers on Tecan and Hamilton robotic systems
5. Presentations
   a. Each student will be assigned to an individual topic of the course and will have to prepare a presentation on it.
   b. Presentations and discussion in form of a Colloquium

The following knowledge is required for the course:

- basic laboratory methods
- basic physics of optics (properties of light, refraction, lenses, fluorescence)
- basic biology of cells (cell anatomy and physiology)

Lab Course: Microbial Biotechnology

- M. Held

Objective

The practical course will consist of a set of 4 experiments.

- to get introduced to liquid handling (pipetting) robotics and learn how to implement a basic workflow
- to be able to run a basic analysis of the data and images obtained with flow cytometers and microscopes

Notes and guidelines will be provided at the beginning of the course.

Prerequisites / notice

- basic biology of cells (cell anatomy and physiology)
- basic physics of optics (properties of light, refraction, lenses, fluorescence)
- basic laboratory methods

The practical course will consist of a set of 4 experiments.

For each experiment, the student will be required to:

- understand the theoretical concept behind the experiment
- plan the experiment
- engineer the devices
- execute the experiments and acquire data
- evaluate and analyze the data
- report and discuss the results

A good quality of the final report will be expected and be an important criterion.
Students will learn the foundations of monoseptic working practice and create and screen microbial libraries for identification of strains expressing different fluorescent protein (XFP) levels.

### Objective

Students will learn the foundations of monoseptic working practice and create and screen microbial libraries for identification of strains expressing different fluorescent protein (XFP) levels.

### Content

**Block A: Handling and preparation of microbial libraries**

D1: Introduction to microbiological cultures and monoseptic working techniques.

D2: Plasmid-based expression systems and variation of XFP synthesis levels via site-directed RBS mutagenesis.

**Block B: Library screening**

D3: In vivo screening for XFP expression levels.

D4: Analysis of XFP levels via SDS-PAGE analysis. RBS-sequencing.

**Block C: Hit recovery and validation**

D5: In silico analysis of RBS variants.

D6: Cellular XFP content for selected variants at different culture conditions.

**Block D: Data analysis and presentation**

D7: Protein expression analysis. Q&A for reports and presentations.

D8: Final presentations and wrap-up.

### Lecture notes

Material will be provided during the course.

### Literature


### Advanced Courses

Students need to acquire a total of 24 ECTS in this category. The list of advanced courses is a closed list; no other course can be added to this category.

#### Biomelecular-Orientated

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0103-00L</td>
<td>Microtechnology</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>A. Hierlemann</td>
</tr>
</tbody>
</table>

### Abstract

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and systems and all related microfabrication processes.

### Objective

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.

### Content

Introduction to microtechnology, semiconductors, and micro electro mechanical systems (MEMS)

- Fundamentals of semiconductors and band model
- Fundamentals of devices: transistor and diode.
- Silicon processing and fabrication steps
- Silicon crystal structure and manufacturing
- Thermal oxidation
- Doping via diffusion and ion implantation
- Photolithography
- Thin film deposition: dielectrics and metals
- Wet etching & bulk micromachining
- Dry etching & surface micromachining
- Microtechnological processing and fabrication sequence
- Optional: Packaging

### Lecture notes

Handouts in English

### Literature


### Prerequisites / notice

Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitiorium of fundamental physics and quantum theory at the semester beginning can be offered.

### Taught competencies

- Domain A - Subject-specific Competencies: Concepts and Theories assessed
- Domain B - Method-specific Competencies: Analytical Competencies assessed
- Domain C - Social Competencies: Communication assessed
- Domain D - Personal Competencies: Critical Thinking assessed

### 636-0104-00L Biophysical Methods

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biophysical Methods</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>D. J. Müller</td>
</tr>
</tbody>
</table>

### Abstract

Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

### Objective

Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as for research in a biotechnology or pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.
The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course, the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:

- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electronic microscopy: Scanning electron microscopy, transmission electron microscopy, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp technologies: Principles of patch clamp analysis and application, Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

Lecture notes
Hand out will be given to students at lecture.

Literature
Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

Prerequisites / notice
The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.

636-0105-00L Introduction to Biological Computers  W  4 credits  3G  Y. Benenson

Abstract
Biological computers are man-made biological networks that interrogate and control cells and organisms in which they operate. Their key features, inspired by computer science, are programmability, modularity, and versatility. The course will show how to rationally design, implement, and test biological computers using molecular engineering, DNA nanotechnology and synthetic biology.

Objective
The course has the following objectives:

* Familiarize students with parallels between theories in computer science and engineering and information-processing in live cells and organisms
* Introduce basic theories of computation
* Introduce approaches to creating novel biological computing systems in non-living environment and in living cells including bacteria, yeast and mammalian/human cells.

The covered approaches will include:
- Nucleic acids engineering
- DNA and RNA nanotechnology
- Synthetic biology and gene circuit engineering
- High-throughput genome engineering and gene circuit assembly
* Equip the students with computer-aided design (CAD) tools for biocomputing circuit engineering. A number of tutorials will introduce MATLAB SimBiology toolbox for circuit design and simulations
* Foster creativity, research and communication skills through semester-long "Design challenge" assignment in the broad field of biological computing and biological circuit engineering.
Lecture 1. Introduction: what is molecular computation (part I)?
* What is computing in general?
* What is computing in the biological context (examples from development, chemotaxis and gene regulation)
* The difference between natural computing and engineered biocomputing systems

Lecture 2: What is molecular computation (part II) + State machines
1st hour
* Detailed definition of an engineered biocomputing system
* Basics of characterization
* Design challenge presentation

2nd hour
* Theories of computation: state machines (finite automata and Turing machines)

Lecture 3: Additional models of computation
* Logic circuits
* Analog circuits
* RAM machines

Basic approaches to computer science notions relevant to molecular computation. (i) State machines; (ii) Boolean networks; (iii) analog computing; (iv) distributed computing. Design Challenge presentation.

Lecture 4. Classical DNA computing
* Adleman experiment
* Maximal clique problem
* SAT problem

Lecture 5: Molecular State machines through self-assembly
* Tiling implementation of state machine
* DNA-based tiling system
* DNA/RNA origami as a spin-off of self-assembling state machines

Lecture 6: Molecular State machines that use DNA-encoded tapes
* Early theoretical work
* Tape extension system
* DNA and enzyme-based finite automata for diagnostic applications

Lecture 7: Introduction to cell-based logic and analog circuits
* Computing with (bio)chemical reaction networks
* Turing computation with ultrasensitivity and cooperativity
* Specific examples

Lecture 8: Transcriptional circuits I
* Introducing transcription-based circuits
* General features and considerations
* Guidelines for large circuit construction

Lecture 9: Transcriptional circuits II
* Large-scale distributed logic circuits in bacteria
* Toward large-scale circuits in mammalian cells

Lecture 10: RNA circuits I
* General principles of RNA-centered circuit design
* Riboswitches and sRNA regulation in bacteria
* Riboswitches in yeast and mammalian cells
* General approach to RNAi-based computing

Lecture 11: RNA circuits II
* RNAi logic circuits
* RNAi-based cell type classifiers
* Hybrid transcriptional/posttranscriptional approaches

Lecture 12: In vitro DNA-based logic circuits
* DNAzyme circuits playing tic-tac-toe against human opponents
* DNA brain

Lecture 13: Advanced topics
* Engineered cellular memory
* Counting and sequential logic
* The role of evolution
* Fail-safe design principles
Biomolecular Nanotechnology is a broad field that focuses on the study and science of biological materials including DNA, RNA and proteins at length scales below 10 nm. This is a broad overview of the topic with a focus on current research themes.

The objective is to familiarise the students with a broad range of topics related to biotechnology, nanotechnology, and biophysics with a focus on current research and reading of scientific literature.

Tentative list of topics:

1. Distance functions
2. Classification
3. Clustering
4. Feature Selection

Lecture material will be provided in form of slides.

Basic understanding of mathematics, as taught in basic mathematics courses at the Bachelor's level, is assumed.
Literature

Representative literature:
(1) Alberts, Molecular Biology (Ch.2 Cellular chemistry).
(2) Ratner, Biomaterials Science (Ch. 2, 3, 2.4 Polymers & hydrogels).
(3) Walsh, Protein Biochemistry, (Ch. 2, Protein Structure).

636-0117-00L Mathematical Modelling for Bioengineering and Systems Biology

Abstract
Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics.

Objective
The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course covers basic mathematical concepts and tools to explore biochemical reaction dynamics as well as basic concepts from dynamical systems theory. The course aims to deepen the understanding of the presented concepts and the mathematical methods, and to train students to numerically solve and simulate mathematical models.

Content
Biochemical Reaction Modelling

636-0118-00L Introduction to Dynamical Systems with Applications to Biology

Abstract
Many physical systems are dynamic and are characterized by internal variables that change with time. Describing the quantitative and qualitative features of this change is the topic of dynamical systems theory. Dynamical systems arise naturally in virtually all scientific disciplines including physics, biology, chemistry and engineering. This course is a broad introduction to the topic dynamical s

Objective
The goal of this course is to introduce the student to dynamical systems and to develop a solid understanding of their fundamental properties. The theory will be developed systematically, focusing on analytical methods for low dimensional systems, geometric intuition, and application examples from biology. Computer simulations using matlab will be used to demonstrate various concepts

Content
A dynamical view of the world; the importance of nonlinearity; solutions of differential equations; solving equations on the computer; the phase plane; fixed points and stability; line analysis; classification of linear systems; Liapunov functions and nonlinear stability: cycles and oscillations; bifurcations and bifurcation diagrams. Many biological examples will be used through the course to demonstrate the concepts

Lecture notes
Will be provided as needed.

Literature

636-0118-00L Mathematical Modelling for Bioengineering and Systems Biology

Prerequisites / notice
Prerequisites: Calculus; a first course in differential equations; basic linear algebra (eigenvalues and eigenvectors); Matlab programming.

636-0109-00L Stem Cells: Biology and Therapeutic Manipulation

Abstract
Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

Objective
Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.

Content
We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

636-0123-00L Problem-Based Approach to Spatial Biology

Abstract
This course entails lectures in tissue physiology, spatial methodologies and grantsmanship. In the project part, small working groups will perform the entire scientific process around formulating a research proposal with the aid of tutors.

Objective
The students will understand the current state of research and novel methodologies in spatial biology and tissue physiology. They will obtain the necessary toolkits to independently identify open research problems in various areas of spatial biology, to address these problems with suitable experimental strategies, and to formulate their approach in a research proposal.

Content
We will use a problem-based approach to explore the way in which single cells collaborate within tissues to achieve their common functions. A thorough comprehension of these tissue components is crucial for advancing our knowledge of normal homeostasis and pathophysiology; disrupted cellular interactions can lead to decreased tissue function or even carcinogenesis.

The project work will be conducted in small groups in guidance of tutors. Each group will focus on a different topic in spatial biology and will review the corresponding literature. They will identify open problems of interest in this area and will summarize their findings in a short, written review. The students will then develop an appropriate experimental strategy to address a question of interest and write a research proposal that features their approach. The final stage of the project work enable the students to practice the presentation of their research proposals and critical evaluation.
Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The

Abstract

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.

Content

Introduction to microtechnology, semiconductors, and micro electro mechanical systems (MEMS)

- Fundamentals of semiconductors and band model
- Fundamentals of devices: transistor and diode.
- Silicon processing and fabrication steps
- Silicon crystal structure and manufacturing
- Thermal oxidation
- Doping via diffusion and ion implantation
- Photolithography
- Thin film deposition: dielectrics and metals
- Wet etching & bulk micromachining
- Dry etching & surface micromachining
- Microtechnological processing and fabrication sequence
- Optional: Packaging

Lecture notes

Handouts in English

Literature


Prerequisites

Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitorium of fundamental physics and quantum theory at the semester beginning can be offered.

Taught competencies

Domain A - Subject-specific Competencies
  - Concepts and Theories

Domain B - Method-specific Competencies
  - Analytical Competencies

Domain C - Social Competencies
  - Communication

Domain D - Personal Competencies
  - Critical Thinking

The information on the web can be updated until the beginning of the semester.

Courses will be provided during the course.

This course requires independent group work.

System-Orientated

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<thead>
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<th>Number</th>
<th>Title</th>
<th>Type</th>
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<td>636-0103-00L</td>
<td>Microtechnology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Hierlemann</td>
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Abstract

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the fabrication of mostly silicon-based microdevices and -systems and all related microfabrication processes.

Objective

Students are introduced to the basics of microtechnology, cleanroom, semiconductor and silicon process technologies. They will get to know the different fabrication methods for various microdevices and systems.

Content

Introduction to microtechnology, semiconductors, and micro electro mechanical systems (MEMS)

- Fundamentals of semiconductors and band model
- Fundamentals of devices: transistor and diode.
- Silicon processing and fabrication steps
- Silicon crystal structure and manufacturing
- Thermal oxidation
- Doping via diffusion and ion implantation
- Photolithography
- Thin film deposition: dielectrics and metals
- Wet etching & bulk micromachining
- Dry etching & surface micromachining
- Microtechnological processing and fabrication sequence
- Optional: Packaging

Lecture notes

Handouts in English

Literature


Prerequisites

Fundamentals in physics and physicochemistry (orbital models etc.) are required, a repetitorium of fundamental physics and quantum theory at the semester beginning can be offered.

Taught competencies

Domain A - Subject-specific Competencies
  - Concepts and Theories

Domain B - Method-specific Competencies
  - Analytical Competencies

Domain C - Social Competencies
  - Communication

Domain D - Personal Competencies
  - Critical Thinking

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<td>W</td>
<td>4</td>
<td>3G</td>
<td>D. J. Müller</td>
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Abstract

Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

Objective

Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as for research in a biotechnology or a pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.

Content

The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught will include:

- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electron microscopy: Scanning electron microscopy, transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp technologies: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

Lecture notes

Hand out will be given to students at lecture.

Literature

Methods in Molecular Biophysics (5th edition), Serdyuk et al., Cambridge University Press

Prerequisites

The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.
Abstract

Biological computers are man-made biological networks that interrogate and control cells and organisms in which they operate. Their key features, inspired by computer science, are programmability, modularity, and versatility. The course will show how to rationally design, implement and test biological computers using molecular engineering, DNA nanothechnology and synthetic biology.

Objective

The course has the following objectives:

* Familiarize students with parallels between theories in computer science and engineering and information-processing in live cells and organisms
* Introduce basic theories of computation
* Introduce approaches to creating novel biological computing systems in non-living environment and in living cells including bacteria, yeast and mammalian/human cells.

The covered approaches will include
- Nucleic acids engineering
- DNA and RNA nanotechnology
- Synthetic biology and gene circuit engineering
- High-throughput genome engineering and gene circuit assembly

* Equip the students with computer-aided design (CAD) tools for biocomputing circuit engineering. A number of tutorials will introduce MATLAB SimBiology toolbox for circuit design and simulations

* Foster creativity, research and communication skills through semester-long "Design challenge" assignment in the broad field of biological computing and biological circuit engineering.
Lecture 1. Introduction: what is molecular computation (part I)?
* What is computing in general?
* What is computing in the biological context (examples from development, chemotaxis and gene regulation)
* The difference between natural computing and engineered biocomputing systems

Lecture 2: What is molecular computation (part II) + State machines
1st hour
* Detailed definition of an engineered biocomputing system
* Basics of characterization
* Design challenge presentation

2nd hour
* Theories of computation: state machines (finite automata and Turing machines)

Lecture 3: Additional models of computation
* Logic circuits
* Analog circuits
* RAM machines

Basic approaches to computer science notions relevant to molecular computation. (i) State machines; (ii) Boolean networks; (iii) analog computing; (iv) distributed computing. Design Challenge presentation.

Lecture 4. Classical DNA computing
* Adleman experiment
* Maximal clique problem
* SAT problem

Lecture 5: Molecular State machines through self-assembly
* Tiling implementation of state machine
* DNA-based tiling system
* DNA/RNA origami as a spin-off of self-assembling state machines

Lecture 6: Molecular State machines that use DNA-encoded tapes
* Early theoretical work
* Tape extension system
* DNA and enzyme-based finite automata for diagnostic applications

Lecture 7: Introduction to cell-based logic and analog circuits
* Computing with (bio)chemical reaction networks
* Turing computation with ultrasensitivity and cooperativity
* Specific examples

Lecture 8: Transcriptional circuits I
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* General features and considerations
* Guidelines for large circuit construction

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* Large-scale distributed logic circuits in bacteria
* Toward large-scale circuits in mammalian cells

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* General approach to RNAi-based computing

Lecture 11: RNA circuits II
* RNAi logic circuits
* RNAi-based cell type classifiers
* Hybrid transcriptional/posttranscriptional approaches

Lecture 12: In vitro DNA-based logic circuits
* DNAzyme circuits playing tic-tac-toe against human opponents
* DNA brain

Lecture 13: Advanced topics
* Engineered cellular memory
* Counting and sequential logic
* The role of evolution
* Fail-safe design principles
636-0108-00L

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**


Lecture notes

Lecture notes will be available online.

Literature

As a way of general introduction, the following two review papers could be useful:


Basic knowledge of molecular biology is assumed.

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636-0018-00L

**Abstract**

Data Mining, the search for statistical dependencies in large databases, is of utmost important in modern society, in particular in biological and medical research. This course provides an introduction to the key problems, concepts, and algorithms in data mining, and the applications of data mining in computational biology.

**Objective**

The goal of this course is to train the students to gain an understanding of data mining problems and algorithms to solve these problems, in particular in biological and medical applications.

**Content**

The goal of the field of data mining is to find patterns and statistical dependencies in large databases, to gain an understanding of the underlying system from which the data were obtained. In computational biology, data mining contributes to the analysis of vast experimental data generated by high-throughput technologies, and thereby enables the generation of new hypotheses.

In this course, we will present the algorithmic foundations of data mining and its applications in computational biology. The course will feature an introduction to popular data mining problems and algorithms, reaching from classification via clustering to feature selection. This course is intended for both students who are interested in applying data mining algorithms and students who would like to gain an understanding of the key algorithmic concepts in data mining.

Tentative list of topics:

1. Distance functions
2. Classification
3. Clustering
4. Feature Selection

Lecture notes

Handout during the course.

Literature

Lecture notes will be provided in form of slides.

Prerequisites / notice

Basic understanding of mathematics, as taught in basic mathematics courses at the Bachelor's level.

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636-0117-00L

**Abstract**

Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics. The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course covers basic mathematical concepts and tools to explore biochemical reaction dynamics as well as basic concepts from dynamical systems theory. The exercises serve to deepen the understanding of the presented concepts and the mathematical methods, and to train students to numerically solve and simulate mathematical models.

**Objective**

Biochemical Reaction Modelling


**Content**

Lecture notes

Handout during the course.

Literature

Lecture notes will be provided as needed.

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636-0118-00L

**Abstract**

Many physical systems are dynamic and are characterized by internal variables that change with time. Describing the quantitative and qualitative features of this change is the topic of dynamical systems theory. Dynamical systems arise naturally in virtually all scientific disciplines including physics, biology, chemistry and engineering. This course is a broad introduction to the topic dynamical systems and covers basic mathematical concepts and tools to explore dynamical systems theory.

**Objective**

The goal of this course is to introduce the student to dynamical systems and to develop a solid understanding of their fundamental properties. The theory will be developed systematically, focusing on analytical methods for low dimensional systems, geometric intuition, and application examples from biology. Computer simulations using Matlab will be used to demonstrate various concepts.

**Content**

A dynamical view of the world; the importance of nonlinearity; solutions of differential equations; solving equations on the computer; the phase plane; fixed points and stability; linear stability analysis; classifications of linear systems; Liapunov functions and nonlinear stability; cycles and oscillations; bifurcations and bifurcation diagrams. Many biological examples will be used through the course to demonstrate the concepts.

Lecture notes

Lecture notes will be available online.
Biology is becoming increasingly quantitative and mathematical modeling is now an integral part of biological research. In many biological

We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as

We will use a problem-based approach to explore the way in which single cells collaborate within tissues to achieve their common

The aim of this course is to introduce certain topics in Probability Theory and Stochastic Processes with Applications to Biology that have been specifically selected

Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health

Infection Biology, Molecular Biology, Nanosciences.

The project work will be conducted in small groups in guidance of tutors. Each group will focus on a different topic in spatial biology and will review the corresponding literature. They will identify open problems of interest in this area and will summarize their findings in a short, written review. The students will then develop an appropriate experimental strategy to address a question of interest and write a research proposal that features their approach. The final stage of the project work enable the students to practice the presentation of their research proposals and critical evaluation.

Literature

- Single cell technologies
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Relevant molecular biology
- Cell fates and their molecular control by transcription factors and signalling pathways
- Relevant basic cell biology and developmental biology
- Induced stem cells by directed reprogramming
- Embryonic and adult stem cells and their niches
- Relevant molecular biology
- Cell culture systems
- Cell physiology, spatial methodologies and grantsmanship. In the project part, small working groups will perform the entire scientific process around formulating a research proposal with the aid of tutors.


This course entails lectures in tissue physiology, spatial methodologies and grantsmanship. In the project part, small working groups will perform the entire scientific process around formulating a research proposal with the aid of tutors.


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Content

The first half of the course will cover the basics of Probability Theory while the second half will delve into the theory of Stochastic Processes. Below is the list of topics that will be covered in the course.

1. The mathematical representation of random phenomena: The probability space, properties of the probability measure, Independence of events, Conditional probability and Bayes formula, applications to parameter inference.


3. Convergence of Random Variables: Modes of convergence, Laws of large numbers, the central limit theorem, the law of the iterated logarithm, Applications to the analysis of cell population data.


Literature

While no specific textbook will be followed, much of the material and homework problems will be taken from the following books:


Prerequisites / notice

The course will involve a healthy balance between mathematical rigor (theorem proving) and biological applications. Students are expected to have a good grasp of Linear Algebra and Multivariable Calculus. Basic knowledge of set theory will also be needed. Students should be prepared for abstract reasoning.

636-0901-00L Computational Biology W 3 credits 2V 4+2A T. Vaughan

Abstract

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phyloodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.

Literature

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.cbb.ethz.ch/news-events.html

For the Zurich-based students without R experience, we recommend the R course http://www.vzv.ethz.ch/Vorungsverzeichnis/erleineinheit/view?semkez=2016W&ansicht=KATALOGDATEN&erleineinheitid=123546&lang=de, or working through the script provided as part of this R course.

636-0901-00L Advanced Immunology I W 2 credits 2V external organisers

636-0901-00L Developmental Neuroscience W 2 credits 2V external organisers

636-0901-00L Molecular Medicine I W 2 credits 2V external organisers

636-0901-00L Spatio-Temporal Modelling in Biology W 4 credits 3G D. Iber

This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.
Objective

Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

Content

1. Introduction to Modelling in Biology
2. Morphogen Gradients
3. Dynamical Systems
4. Cell-cell Signalling (Dr Boareto)
5. Travelling Waves
6. Turing Patterns
7. Chemotaxis
8. Mathematical Description of Growing Biological Systems
9. Image-Based Modelling
10. Tissue Mechanics
11. Cell-based Tissue Simulation Frameworks
12. Plant Development (Dr Dumont)
13. Growth Control
14. Summary

Lecture notes

All lecture material will be made available online

https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html

Literature

The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessarily to follow the course:

- Murray, Mathematical Biology; Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al, Computational Cell Biology, Springer
- Szallasi et al, System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Kreyszig, Engineering Mathematics, Wiley

Prerequisites / notice

The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

636-0510-00L Proteomics and Drug Discovery Research

| Credit | W | 2 credits | 2V | external organisers |

636-0119-00L Introduction to Statistics and R

| Credit | W | 6 credits | 3G+2A | J. Kuipers |

Abstract

This course offers a practical introduction to the fundamentals of data analysis and R

Objective

To acquire the statistical understanding to design an appropriate analysis and the practical skills to implement the analysis in R and present the results.

Content

Data analysis is fundamental for arriving at scientific conclusions and testing different hypotheses. This course offers a hands-on introduction to statistical analyses including: exploratory data analysis, testing differences in populations, p-values, power calculations, multiple testing, confounding, linear regression, maximum likelihood, model selection, and logistic regression; along with the fundamentals of R programming including markdown and data handling with the tidyverse.

Lecture notes

Lecture slides will be available

Prerequisites / notice

Access to Rstudio with some markdown and tidyverse packages installed.

636-0120-00L Introduction to Programming

| Credit | Z | 0 credits | 1G | D. S. Roqueiro |

Abstract

This is a voluntary programming course BEFORE the start of the semester (September 2021). It is addressed primarily at students of the MSc Biotechnology (and MSc CBB). Other students may send a request to participate to: student-admin@bsse.ethz.ch

Objective

The goal of this course is to give students, who have no prior programming background, a solid introduction to algorithm development and its successive implementation in a programming language. For students with previously acquired programming skills, the course will serve as a reinforcement of key aspects of structured programming in addition to providing a well-rounded introduction to MATLAB, R and Python.

Content

The course is structured in four main pillars:

- Logical thinking: Translating a problem into a conceptual sequence of computational steps. For example: [Problem] What is the GC content of a given DNA string? [Logical steps]
  i) Iterate through all nucleotides in the DNA string, one by one
  ii) Count the Cs or Gs
  iii) Divide the count of Cs or Gs by the length of the DNA string
  iv) Report the result.

- Writing code: Full introduction to the MATLAB programming languages (R and Python will also be covered). Solutions to all exercises will be provided in MATLAB, R and Python. Creation of programming projects with an integrated development environment (IDE).
- Primer of Unix commands: Command-line examples on how to access servers and computing resources at the D-BSSE. Submission of a request to participate to: student-admin@bsse.ethz.ch

Lecture notes

Available on course website (Moodle):

https://moodle-app2.let.ethz.ch/course/view.php?id=15235

Publicly available material (links will be posted on the course website)
Objective
After this course, the student is expected to understand and be able to apply the basics of supramolecular chemistry: host-guest interactions, host design, self-assembly and simple enzyme mimetics.

Content
This course provides an introduction to supramolecular chemistry. Prior knowledge in supramolecular chemistry is not a prerequisite for this course. We will first cover the basic concepts of supramolecular chemistry: non-covalent interactions, host-guest chemistry, binding constant determination and binding strength. Subsequently, we will take a closer look at how to bind different species: cations, anions and neutral organic molecules. Towards the end of the semester, we will cover self-assembly processes and applications of supramolecular structures as simple enzyme mimetics.

Lecture notes
The lecture slides are provided online via ADAM. No additional literature is required. If additional information is desired, the book “Supramolecular Chemistry” by Jonathan W. Steed and Jerry L. Atwood (John Wiley & Sons) is recommended.

GESS Science in Perspective
see GESS Science in Perspective: Language Courses ETH/UZH
see GESS Science in Perspective: Type A: Enhancement of Reflection Capability
Recommended GESS Science in Perspective (Type B) for D-BSSE.

Biotechnology Master - Key for Type

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Key for Hours

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ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Core Courses

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
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<td>072-0101-00L</td>
<td>Module 1: Foundations of Digitalisation</td>
<td>O</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
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<td>Abstract</td>
<td>Key terms: Digital transformation is more than digitisation of existing processes and information</td>
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<tr>
<td>Objective</td>
<td>Independently of the building industry, Module 1 initially provides information about the characteristics of digitalisation through its principles and rules, enabling the participants to independently recognise the short-term and long-term changes that are resulting from it.</td>
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<tr>
<td>Content</td>
<td>The first module addresses the topic of digitalisation and digital transformation in a holistic sense. It is much more than converting documents into PDFs or using software. It is about transforming processes, resources and information into a consistent and efficient digital system to make life easier for employees and customers. This journey always involves change. From the perspective of other industries, we first build up a basic understanding and discuss the opportunities and risks.</td>
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<tr>
<td>Lecture notes</td>
<td>How do the experiences of other industries help us? What can be derived from them? Why is BIM only a small part and why is the future of BIM not BIM?</td>
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<td>Literature</td>
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<td>Abstract</td>
<td>Key terms: &quot;Behaviour for Collaboration&quot; - Structural questions on collaboration and the patterns of behaviour.</td>
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<tr>
<td>Objective</td>
<td>In Module 2, we break from the theoretical idea of a purely technology-based, better collaboration and look at the situation realistically in order to be able to understand and develop new solutions and requirements.</td>
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<tr>
<td>Content</td>
<td>The usual approach towards digital transformation is to train people to use new technologies. In contrary, we ask for the specific challenges and problems people have with change. We learn to understand viewpoints of different partners within building projects and new solutions to specific problems.</td>
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<td>072-0103-00L</td>
<td>Module 3: Foundation of Automation</td>
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<tr>
<td>Abstract</td>
<td>Key terms: Managed data, semantics and file formats</td>
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<td>Objective</td>
<td>Module 3 we leave behind the negative images from the early days of automation. A gloomy and misanthropic image of automation - both a bliss and a curse. We get to know the positive sides and learn to apply them. How do we become a sustainable &quot;Formula 1&quot;?</td>
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<tr>
<td>Content</td>
<td>What does it take to be able to work together in a digitally networked environment? How many &quot;techie genes&quot; are needed to work efficiently and effectively with structured data? The third module gives an insight into the principles of data architectures, data formats, attributes and platform technology. Machine readability as an important requirement but also as a clear challenge e.g. to security requirements.</td>
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<tr>
<td>Abstract</td>
<td>Key terms: Added value of digital transformation, distributed data management, digital twin, logistics and robotics.</td>
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<td>Objective</td>
<td>Using specific examples, Module 4 illustrates the foundations and versatility of building information modeling (BIM), enabling participants to deal with the concepts, applications and mechanisms involved.</td>
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<tr>
<td>Content</td>
<td>&quot;Highway to hell or highway to haven&quot; - the question of a clear and simple roadmap is always at the heart of a digital transformation. &quot;Value creation&quot; is a central goal. Digitalisation is often seen as a strategy from the productivity gap. The fourth module shows how strategic goals can be developed in a roadmap and implemented in practice and how the individual shareholders and stakeholders participate.</td>
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<td>Module 5: New Business Modelle</td>
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<td>Abstract</td>
<td>Key terms: Business models, cultural change, disruption, evolution, lean methods</td>
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<tr>
<td>Objective</td>
<td>Module 5 focuses on cultural change, innovation, disruption or evolution? In this last model, we learn to question and discover what the 17 Sustainable Goals mean for our industry.</td>
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<td>Content</td>
<td>As a final module, new business models are discussed and explored. Examples will be used to explore patterns and interfaces and to analyse what is needed today and in the future for a successful and sustainable development of the sector. How can innovative ideas move us forward? What can we learn from design thinking? Why is it important for people to have useful and understandable measurable values? How do the 17 Sustainable Goals influence our industry?</td>
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### Term Paper

The Term Paper is offered in spring semesters only.
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### ECTS
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<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
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<td>- Phases and services</td>
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<td>- Due diligence and duty of loyalty</td>
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<td>- Duties and tasks, liability</td>
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<td>The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.</td>
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<td>- Motivation and conflict resolution</td>
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<td>- Decision making</td>
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### Term Paper

**Offered in the Spring Semester.**
### CAS ARC in Project Leadership - Key for Type

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### Key for Hours

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</table>

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Module 3: Economic Interest

With more than CHF 3,585 billion (excluding land), Switzerland is the largest national capital. It grows by around 4.7 per cent each year, but key words: construction and real estate market, micro and macro environment.

Objective
In Module 1, by interpreting the snapshot of one’s own enterprise and opportunities and dangers to appreciate.

Content
Introductory module “Enterprise” considers the role of organizations in the economic network of markets and their identity. It presents the peculiarities of planning offices as a service provider, shows different types of companies and discusses the business cycle from founding to succession planning. In addition, the branch-specific development of leadership and organizational models as well as the problem of access to international markets are examined. Accompanying the basics of a general business model for service companies are taught and key criteria defined.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 4: Course of Action

Building and breaking off is understood as an energy and material flow.

Objective
The participants understand a property in the context of a life cycle.

Content
The structure and nomenclature of the interventions in the stock are presented and models for the registration and calculation of the various depths of intervention in dealing with a existing property and their effects are known.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 5: Life Cycle and Resources

Does not take place this semester.

Objective
Preservation of value, increase in value, destruction of value and replacement construction.

Content
The participants understand a property in the context of a life cycle.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
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Core Courses

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Term Paper

The term paper is offered in spring semester only.

### CAS ARC in Real Estate Strategies urban-peri-urban - Key for Type

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ECTS (European Credit Transfer and Accumulation System)

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CAS ARC in Unternehmensführung

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<td></td>
<td>Key terms: Market, purpose and business model</td>
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<td>The aim is to use a snapshot in time to interpret one’s own company and become able to assess opportunities and risks.</td>
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<td>The “company” module considers the role of organisations within the economic network of the markets and the nature of their identity. It presents the special aspects of planning offices as service providers, illustrates various types of company, and discusses companies’ life-cycle as they move from their founding to the period of planning for the succession. Both sector-specific development of management and organizational models and also the problems of obtaining access to international markets are also investigated. Alongside this, the foundations of a generally valid business model for service companies are described and key criteria are defined.</td>
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<td>Key terms: Competence, communication and network</td>
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<td>The aim is to become able to analyse and implement the processes and instruments used for acquisition in one’s own company.</td>
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<td>Acquisition represents a separate project in entrepreneurial activity, since all the activities involved in obtaining a commission fall under this term. The “acquisition” module focuses on imparting basic knowledge of networking and professional dialogue. Both of these tools require an assessment of one’s own situation with regard to competence, resources and customer relations. The conversation is a direct interaction: everyone involved is both an addressee and also basically an equal interlocutor. Networking can be learned: situational “small talk,” social competence and a healthy ability to communicate can be learned.</td>
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<td>Key terms: Planning, positioning and identity</td>
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<td>The aim is to become familiar with the tools used in marketing and able to use them in specific situations.</td>
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<td>Marketing means orienting company activities towards market demands. Communication between suppliers, clients and the competition plays the decisive role here. The “marketing” module illustrates the foundations of marketing planning for architects and engineers. The essential definitions are provided and the core tasks involved in marketing are described. On this basis, the way in which a marketing plan is developed is explained and strategic and operational marketing planning is described in detail. The topics of branding and the opportunities represented by press and public relations work for architects and planners round out the “marketing” module.</td>
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<td>Key terms: Cost accounting, budgeting and controlling</td>
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<td>The aim is to become able to analyse one’s own company’s financial resources in detail, interpret key parameters for the current situation and act accordingly.</td>
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<td></td>
<td>Financial management means achieving the target company output with costs that are as low as possible, and in the longer term to create secure asset and capital structures. The tasks involved in financial management in a planning office include establishing a well-structured accounting department, careful cost accounting, sound budgeting and an effective controlling system. On the basis of a practical financial structure for architecture and engineering offices, the “financial management” module presents the information needed to carry these tasks out in a professional and responsible way.</td>
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<tr>
<td></td>
<td>License notes</td>
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<tr>
<td></td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program.</td>
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<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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<tr>
<td>072-0405-00L</td>
<td>Module 5: Digitalisation</td>
<td>O</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
</tr>
<tr>
<td></td>
<td>Only for CAS ARC in Unternehmensführung and MAS in Architecture, Real Estate, Construction.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Key terms: Strategy, potentials and digital planning</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>The aim is to become familiar with the current practical work involved in IT in planning companies and be able both to analyse the specific challenges it implies and also to infer one’s own prospects for development in this context. In addition, thought needs to be given to the way in which the value creation provided by digitalisation influences one’s own company.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>IT refers on the one hand to information and data processing in a company, and on the other to the hardware and software components needed for the purpose. This “information technology” module focuses on potential strategies for company management in the IT field. The focus is not on the use of any individual programme, but on taking conscious decisions for or against IT components in one’s own company in order to obtain helpful support in one’s everyday work. The strengths, weaknesses, opportunities and risk of this strategy suggest possible potentials.</td>
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<td></td>
<td>License notes</td>
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<td></td>
<td>The participants will present their own theses on entrepreneurship and open them up for discussion in the plenary session.</td>
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<tr>
<td></td>
<td>Literature</td>
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</table>

Term Paper

Offered in the Spring Semester.
<table>
<thead>
<tr>
<th>CAS ARC in Unternehmensführung - Key for Type</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

### Key for Hours

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

ECTS | European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# CAS in Advanced Materials and Processes

## Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>
| 344-0100-00L | CAS Module in Advanced Materials and Processes  
Only for CAS in Advanced Materials and Processes.  
The enrolment is done by the MaP executive office. | O    | 12 credits | 26A   | Professors      |

### Abstract

CAS AMaP participants are offered a MaP professor as a mentor together with whom they design their study plan along an individually-specified focus area in 'Advanced Materials and Processes'. Building on the individual expertise, interests and needs of the participants, the customised CAS AMaP module consists of the elements (i) research project, (ii) courses and lectures, (iii) knowledge transfer.

### Objective

The CAS AMaP module is fully customisable, building on the expertise of technical specialist professionals and aims at:
- training skills at the frontiers of the current state of research in Advanced Materials and Processes,
- deepening technical know-how with state-of-the-art knowledge in the specified focus area, and
- advancing practical competencies in the impart of expertise and knowledge transfer across disciplines and educational levels.

### Content

Depending on individual interests and needs of the technical specialist professionals, the CAS AMaP module consists of the elements:
I. conducting a research project in the mentor’s group, addressing fundamental, development or applied problems, considering theoretical and/or experimental aspects,
II. individual schedule of courses and lectures with state-of-the-art knowledge, and
III. sharing of know-how in, e.g. seminars and interactive formats, thereby enhancing bidirectional knowledge transfer.

### CAS in Advanced Materials and Processes - Key for Type

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<thead>
<tr>
<th>W+</th>
<th>W</th>
<th>E-</th>
<th>Z</th>
<th>Dr</th>
<th>O</th>
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</thead>
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<td>Eligible for credits</td>
<td>Recommended, not eligible for credits</td>
<td>Courses outside the curriculum</td>
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### Key for Hours

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<thead>
<tr>
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<th>K</th>
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<tbody>
<tr>
<td>lecture</td>
<td>lecture with exercise</td>
<td>exercise</td>
<td>seminar</td>
<td>colloquium</td>
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<th>A</th>
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<th>R</th>
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<tr>
<td>practical/laboratory course</td>
<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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</tbody>
</table>

### ECTS

European Credit Transfer and Accumulation System

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

CAS in Applied Earth Sciences

▸ Modules Geo-Resources
The Module Geo-Resources runs over two semesters (FS and HS) and is offered every three years.

Takes place in FS22 + HS22

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>669-0102-00L</td>
<td>Autumn Course: Utilisation of Geothermal Energy</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>M. O. Saar, to be announced</td>
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<tr>
<td></td>
<td>Does not take place this semester. Only for CAS in Angewandten Erdwissenschaften.</td>
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</table>

▸ Modules Geo-Constructions
The Module Geo-Constructions runs over two semesters (FS and HS) and is offered every three years.

Takes place in FS23 + HS23

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>669-0202-00L</td>
<td>Autumn Course: Engineering Geology in Underground Constructions</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>S. Löw</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester. Only for CAS in Angewandten Erdwissenschaften.</td>
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▸ Modules Geo-Risks
The Module Geo-Risks runs over two semesters (FS and HS) and is offered every three years.

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<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>669-0302-00L</td>
<td>Autumn Course: Landslide Processes and Hazards</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>S. Löw, J. Aaron, A. Manconi</td>
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<td>Only for CAS in Angewandten Erdwissenschaften.</td>
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</table>

Abstract
The autumn course covers landslides in the broader sense, large slope movements and flowing mass movements in soil and rock. The course provides current and new knowledge needed for classification, determination of the relevant processes and estimation of the temporal behaviour of geological mass movements.

Objective
The participants learn which investigations and measurements can be used to improve the hazard analysis in a targeted manner, especially for more complex slope instabilities.

CAS in Applied Earth Sciences - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
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<tr>
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<td>Eligible for credits and recommended</td>
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<tr>
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<td>Eligible for credits</td>
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<tr>
<td>E-</td>
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<tr>
<td>Z</td>
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</tr>
<tr>
<td>Dr</td>
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</table>

Key for Hours

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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
CAS in Applied Statistics

### Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>447-0649-01L</td>
<td>Applied Statistical Regression I</td>
<td>O</td>
<td>4 credits</td>
<td>1V+1U</td>
<td>M. Tanadini</td>
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<tr>
<td></td>
<td>Only for DAS and CAS in Applied Statistics.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Simple and multiple regression models, with emphasis on practical aspects and interpretation of results, analysis of residuals and model selection.</td>
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<td>Objective</td>
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<tr>
<td>447-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design I</td>
<td>O</td>
<td>3 credits</td>
<td>1V+1U</td>
<td>L. Meier</td>
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<td>Only for DAS and CAS in Applied Statistics.</td>
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<td></td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs.</td>
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<td>Objective</td>
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<tr>
<td></td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<td>Literature</td>
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### Further Courses

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<th>Lecturers</th>
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<tbody>
<tr>
<td>447-0649-02L</td>
<td>Applied Statistical Regression II</td>
<td>Z</td>
<td>2 credits</td>
<td>1V+1U</td>
<td>C. Renaux</td>
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<tr>
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<tr>
<td></td>
<td>Generalized linear models (GLMs) and basic ideas of more advanced regression models.</td>
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<tr>
<td></td>
<td>Understanding the concept and flexibility of generalized linear models and correct interpretation of the corresponding model outputs.</td>
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<tr>
<td>447-0625-02L</td>
<td>Applied Analysis of Variance and Experimental Design II</td>
<td>Z</td>
<td>3 credits</td>
<td>1V+1U</td>
<td>L. Meier</td>
</tr>
<tr>
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<td>Only for DAS and CAS in Applied Statistics.</td>
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<td></td>
<td>Random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Participants will be able to plan and analyze sophisticated experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
<td>447-6221-00L</td>
<td>Nonparametric Regression</td>
<td>W</td>
<td>1 credit</td>
<td>1G</td>
<td>M. Mächler</td>
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<tr>
<td></td>
<td>Special Students “University of Zurich (UZH)” in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to <a href="mailto:registrar@ethz.ch">registrar@ethz.ch</a>. The Registrar's Office will then register you for the course.</td>
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<td>Abstract</td>
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<td>This course focusses on nonparametric estimation of probability densities and regression functions. These recent methods allow modelling without restrictive assumptions such as ‘linear function’. These smoothing methods require a weight function and a smoothing parameter. Focus is on one dimension, higher dimensions and samples of curves are treated briefly. Exercises at the computer.</td>
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<td>Objective</td>
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<td></td>
<td>Knowledge on estimation of probability densities and regression functions via various statistical methods. Understanding the choice of weight function and of the smoothing parameter, also done automatically. Practical application on data sets at the computer.</td>
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<tr>
<td>447-6257-00L</td>
<td>Repeated Measures</td>
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<td>Objective</td>
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<td>Participants will gain the ability of recognizing repeated measures and to analyze them adequately. They will know how to deal with pseudoreplicates.</td>
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<tr>
<td>447-6289-00L</td>
<td>Sampling Surveys</td>
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<td>2 credits</td>
<td>1G</td>
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<td>Does not take place this semester.</td>
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<td></td>
<td>The elements of a sample survey are explained. The most important classical sample designs (simple random sampling and stratified random sampling) with their estimation procedures and the use of auxiliary information including the Horvitz-Thompson estimator are introduced. Data preparation, non-response and its treatment, variance estimation and analysis of survey data is discussed.</td>
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<td>Objective</td>
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<td></td>
<td>Knowledge of the Elements and the process of a sample survey. Understanding of the paradigm of random samples. Knowledge of simple random sampling and stratified random sampling and capability to apply the corresponding methods. Knowledge of further methods of sampling and estimation as well as data preparation and analysis.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Introduction to the statistical methods of survey research</td>
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</table>

|          | Nonparametric and Resampling Methods      | Z    | 2 credits | 2G    | L. Meier, D. Kuonen |
|          | Special Students “University of Zurich (UZH)” in the |      |         |       |                   |

Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

For classical parametric models there exist optimal statistical estimators and test statistics whose distributions can often be determined exactly. The methods covered in this course allow for finding statistical procedures for more general models and to derive exact or approximate distributions of complicated estimators and test statistics.

Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

This course is part of the programme for the certificate and diploma in Advanced Studies in Applied Statistics. It is given every second year in the winter semester break.

**Spatial Statistics**

Does not take place this semester.
Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

**Objective**

The course will provide an overview of the basic concepts and stochastic models that are commonly used to model geostatistical data sets. In addition, the participants will learn a number of geostatistical techniques and acquire some familiarity with software that is useful for analysing spatial data.

**Content**

After an introductory discussion of the types of problems and the kind of data that arise in environmental research, an introduction into linear geostatistics (models: stationary random processes, modelling large-scale spatial patterns by regression, modelling autocorrelation by variogram; kriging; mean-square prediction of spatial data) will be taught. The lectures will be complemented by data analyses that the participants have to do themselves.

**Lecture notes**

Slides, descriptions of the problems for the data analyses and worked-out solutions to them will be provided.

**Literature**


**Data Mining**

Does not take place this semester.
Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

**Abstract**

Block course only on prediction problems, aka "supervised learning".

Part 1, Classification: logistic regression, linear/quadratic discriminant analysis, Bayes classifier; additive and tree models; further flexible ("nonparametric") methods.

Part 2, Flexible Prediction: additive models, MARS, Y-Transformation models (ACE,AVAS); Projection Pursuit Regression (PPR), neural nets.

"Data Mining" is a large field from which in this block course, we only treat so called prediction problems, aka "supervised learning".

**Content**

Part 1, Classification, recalls logistic regression and linear / quadratic discriminant analysis (LDA/QDA) and extends these (in the framework of 'Bayes classifier") to (generalized) additive (GAM) and tree models (CART), and further mentions other flexible ("nonparametric") methods.

Part 2, Flexible Prediction (of continuous or "class" response/target) contains additive models, MARS, Y-Transformation models (ACE, AVAS); Projection Pursuit Regression (PPR), neural nets.

**Lecture notes**

The block course is based on (German language) lecture notes.
Prerequisites / notice
The exercises are done exclusively with the (free, open source) software "R" (http://www.r-project.org). A final exam will also happen at the computers, using R (and your brains!).

447-6273-00L Bayes Methods

W 2 credits 2G

Abstract
conditional probability; bayes inference (conjugate distributions, HDP-areas; linear and empirical bayes); determination of the a-posteriori distribution through simulation (MCMC with R2Winbugs); introduction to multilevel/hierarchical models.

Content
Bayes statistics is attractive, because it allows to make decisions under uncertainty where a classical frequentist statistical approach fails. The course provides an introduction into bayesian methods. It is moderately mathematically technical, but demands a flexibility of mind, which should not underestimated.

Literature

Prerequisites / notice
Prerequisite: Basic knowledge of statistics; Knowledge of R.

447-6191-00L Statistical Analysis of Financial Data

W 2 credits 1G

Abstract

Objective
Getting to know the typical properties of financial data and appropriate statistical models, incl. the corresponding functions in R.

CAS in Applied Statistics - Key for Type

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

Key for Hours

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<td>R</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
CAS in Applied Information Technology
The CAS takes place in Autumn Semester only.

| Module |
|---|---|---|---|---|
| Number | Title | Type | ECTS | Hours | Lecturers |
| 265-0100-00L | Foundations of Programming | O | 3 credits | 2A | L. E. Fässler |

**Abstract**
The initial module offers a practical introduction to some basic concepts and techniques for information processing as well as practical applications of them. The programming language are Python and SQL.

**Objective**
Students learn...
- how to encode a problem into a program, test the program, and correct errors.
- to understand and improve existing code.
- to implement mathematical models as a simulation.

**Content**
The following programming concepts are introduced during this module:

1. Variables, data types
2. Condition check, Loops, logics
3. Arrays
4. Functions
5. Matrices
6. Data management (SQL)

In the practical part of the course, students work on small programming projects with a context from natural sciences. Electronic tutorials are available as preparation.

**Prerequisites / notice**
No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>265-0101-00L</td>
<td>Data Science</td>
<td>O</td>
<td>3 credits</td>
<td>3V</td>
<td>B. Gärtner</td>
</tr>
</tbody>
</table>

**Abstract**
In this module, basic paradigms and techniques in working with data will be discussed, especially towards data security, managing data decentrally, and learning from data.

**Objective**
Participants learn about some important computer science concepts necessary for data science. They understand some of these concepts in detail and see the mathematics behind them.

**Content**
Participants will get an introduction to key computer science concepts underlying current and upcoming technology. The module in particular covers cryptography and digital signatures, networking and distributed algorithms, distributed ledger technology, as well as machine learning (supervised and unsupervised learning). Each topic will be discussed in two different ways: (i) a hands-on and in-depth introduction that allows participants to gain a technical understanding of key ideas. This is supported by simple and concrete examples as well as programming assignments; (ii) a context part that addresses the challenges and limitations encountered in practical applications.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>265-0102-00L</td>
<td>Humans &amp; Machines</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>E. Konukoglu</td>
</tr>
</tbody>
</table>

**Abstract**
This module offers practical knowledge in visual information processing and human computer interactions.

**Objective**
Participants understand basic concepts of visual recognition and human-computer interaction systems.

**Content**
The first part of the module will cover basic theoretical knowledge on visual recognition systems of the last two decades, mostly focusing on the most recent advancements in deep learning and convolutional neural networks. The theoretical knowledge will be supported with practical sessions that will allow participants to gain hands-on experience with most commonly used tools and deepen their understanding of the key concepts. The second part provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>265-0103-00L</td>
<td>Applied Information Technology</td>
<td>O</td>
<td>3 credits</td>
<td>3V</td>
<td>M. Brandis</td>
</tr>
</tbody>
</table>

**Abstract**
This integration module for CAS "Applied Information Technology" links technical understanding of technology with business strategy based on a set of case studies from practice.

**Objective**
Participants will learn how technology affects businesses and practical issues when using new technologies in incumbent organizations based on a set of case studies.

**Content**
Participants will explore how new information technologies change different aspects of a business, and learn how to evaluate specific risks, costs, and benefits of such technologies. The module will shed light on success factors and common pitfalls when implementing new technologies and respective business changes, and it will specifically address the communication between technical experts and business management. The studied cases are currently planned to focus on artificial intelligence, IoT including edge and cloud computing, blockchain and distributed ledger technologies, and cybersecurity and data protection regulations (subject to change).

### CAS in Applied Information Technology - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Notice</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<td>W</td>
<td>Eligible for credits</td>
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</table>

**Dr** Suitable for doctorate

**Z** Courses outside the curriculum

**E-** Recommended, not eligible for credits

### Key for Hours

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

**ECTS**

- **European Credit Transfer and Accumulation System**

- Special students and auditors need special permission from the lecturers.
CAS in Applied Manufacturing Technology

The CAS takes place in Spring Semester only.

Start of the next course: FS 2022

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
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<tbody>
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<td>V</td>
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<td>U</td>
<td>exercise</td>
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<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## CAS in Applied Technology in Energy

The CAS takes place in Spring Semester only.

<table>
<thead>
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<th>Key for Hours</th>
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<tbody>
<tr>
<td>V</td>
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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>seminar</td>
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<td>colloquium</td>
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<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# CAS in Applied Technology: R&D and Innovation

The CAS takes place in Autumn Semester only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>247-0200-00L</td>
<td>Organization of R&amp;D in Tech Companies</td>
<td>O</td>
<td>4 credits</td>
<td>2G</td>
<td>U. Grossner</td>
</tr>
</tbody>
</table>

**Abstract**

This course provides an introduction to research & development, both as a general activity and as a dedicated function within a corporation. Participants will learn how to organize, conduct and manage individual R&D projects as well as groups of projects. We will also look at the various roles that R&D serves within a corporation and how choices regarding the organization of R&D align with these roles.

**Objective**

The aim of this course is to develop the participants’ ability to articulate a coherent plan for R&D activities linked to the business needs of a corporation, including the ability to explain convincingly the rationale, structure, resources and intended outcomes of the R&D.

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<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>247-0201-00L</td>
<td>Innovation Opportunity Analysis</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>J. Jaminet</td>
</tr>
</tbody>
</table>

**Abstract**

The Innovation Opportunity Analysis course is designed as a practical introduction to evaluating technology-based innovation opportunities in a corporate setting. The course will cover several fundamental innovation frameworks and principles before diving deeper into individualized content using the principle of Guided Learning.

**Objective**

The primary goal of the course is to develop the skills needed for identifying technology-based innovation opportunities and for planning successful innovation projects. An additional goal is to prepare participants for their Master's thesis and for lifelong learning in technology-based innovation.

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>247-0202-00L</td>
<td>Innovation and Technology Tools</td>
<td>O</td>
<td>2 credits</td>
<td>4G</td>
<td>U. Grossner, J. Jaminet</td>
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</table>

**Abstract**

This module will provide an introduction to some of the fundamental tools that can be used for evaluating technologies and innovation opportunities.

**Objective**

The goal is to enable participants to use basic innovation and technology evaluation tools within their work setting.

<table>
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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>247-0203-00L</td>
<td>Experiment Selection &amp; Design</td>
<td>O</td>
<td>0 credits</td>
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<td>U. Grossner</td>
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</table>

**Abstract**

This module prepares participants to conduct an experimental project in an ETH lab beginning in the following January as part of the MAS in Applied Technology programme. Participants will prepare a plan and design for the experimental project under the direction of the CAS Programme Director and the relevant ETH lab.

**Objective**

The goal is for participants to learn standard procedures for the planning and design of experiments and to gain practical experience in planning and designing an individual experimental project.

---

## CAS in Applied Technology: R&D and Innovation - Key for Type

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

## Key for Hours

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

## ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

---

CAS in Collaborative Decision Making Under Uncertainty

Takes place only in Spring Semester

Start of the next course: Spring Semester 2022

### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
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</table>

**ECTS**

Special students and auditors need special permission from the lecturers.
**CAS in Cyber Security**

*The CAS takes place in Autumn Semester only.*

### Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>268-0101-00L</td>
<td>Introduction to Information Security</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>P. Schaller, S. Matetic</td>
</tr>
<tr>
<td></td>
<td><em>Only for CAS and DAS in Cyber Security.</em></td>
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</tr>
<tr>
<td>Abstract</td>
<td>In this course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Graduates of the course know the technical foundations of information security and understand the difficulty and complexity involved when trying to build secure systems.</td>
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<tr>
<td>Content</td>
<td>In this new course, the goal is to introduce the fundamentals of information/cyber security from a technical point of view. Along with theory, hands-on experiments are an important building block of the course and help to deepen the students' understanding of the theory parts.</td>
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</tr>
<tr>
<td>268-0201-00L</td>
<td>Information Security Seminar and Project</td>
<td>O</td>
<td>2 credits</td>
<td>2S</td>
<td>S. Matetic</td>
</tr>
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<td><em>Only for CAS and DAS in Cyber Security.</em></td>
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<tr>
<td>Abstract</td>
<td>Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.</td>
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<tr>
<td>Objective</td>
<td>Participants have understood and presented a publication or report on a present topic in information security. By attending other participants presentations students get further introduced to additional current information security related topics/incidents.</td>
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</tr>
<tr>
<td>Content</td>
<td>Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.</td>
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<tr>
<td>268-0202-00L</td>
<td>Contemporary Topics in Cyber Security</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Matetic</td>
</tr>
<tr>
<td></td>
<td><em>Only for CAS and DAS in Cyber Security.</em></td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course is composed of various sub-modules related to Cyber Security taught by experts on the relevant fields.</td>
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<tr>
<td>Objective</td>
<td>Students are expected to see behind the curtain of current research and engineering activities related to Cyber Security. At the same time students are introduced to contemporary challenges in cyber security by renowned experts.</td>
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</tr>
<tr>
<td>Content</td>
<td>The lectures cover contemporary aspects and challenges in Cyber Security. The goal is to present current fields of research/engineering and the latest results. By way of example, Cyber Security Policy is one of sub-modules presented by researchers of the Center for Security Studies at ETH. Besides faculty members of the computer science department, there will be guest lecturers from industry presenting Cyber Security related challenges in their field of activity.</td>
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<tr>
<td>Literature</td>
<td>Will be announced during the course.</td>
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</table>

**CAS in Cyber Security - Key for Type**

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
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<td>Eligible for credits and recommended</td>
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<tr>
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<tr>
<td>E-</td>
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<tr>
<td>Z</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
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</table>

**Key for Hours**

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

**ECTS**

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
This is the first knowledge module in the CAS ELTV. In this module we (1) introduce all participants to the CAS and ETH, (2) get to know in more detail the projects of the participants and how lean innovation plays a role, and (3) discuss important considerations of strategy formation in technology ventures.

### Objective
This module enables participants:
- To understand and select from commercialization strategies available to them (e.g., licensing, partnering, and vertical integration) and respective business model choices
- Assess and generate development options for key internal enabling factors such as IP strategy and key resources and capabilities
- Understand different market research and developments tools (lean start-up vs. technology broadcasting) and select appropriate methods and related KPIs

### Content
This module focuses on elements of entrepreneurial strategy formation and implementation in nascent markets and/or industries. Participants will study commercial options available to them, e.g., technology broadcasting, licensing and partnering, and vertical integration, which is complemented by a practical view on IP strategy, driven by business strategy rather than arbitrary choices. The module also includes the introduction to lean innovation methods incl. agile product development methods and core tools of the lean startup approach.

### Prerequisites / notice
This module is only for CAS ELTV participants.

### Lecture notes
See Online Platform

### Literature
See Online Platform

---

This is the second knowledge module within the CAS ELTV. During this module, we will discuss important themes concerning entrepreneurial team formation and management and practice elements in interactive workshops.

### Objective
This module enables participants:
- To understand key requirements for new venture leadership and how to build effective governance structures for the founding team
- To select and implement approaches and methods to structure productive work relationships within an emerging firm.
- To understand and build the organizational foundations for successful professionalizing of venture operations

### Content
This module zooms in on the design and management of new venture teams in technology-based companies as well as the role of leadership in building successful venture teams. Key contents in this module comprise founder contracts, successful governance structures, and approaches to team performance management. This module also allows participants to understand requirements for venture leadership and professionalizing venture operations as well as building productive work relationship within their emerging firm.

### Prerequisites / notice
This module is only for CAS ELTV participants.

### Lecture notes
See Online Platform

### Literature
See Online Platform

---

This is the third knowledge module within the CAS ELTV. During this module, we will discuss important themes concerning entrepreneurial team formation and management and practice elements in interactive workshops. The module will be extended by intermediary project review meetings.

### Objective
This module enables participants:
- To understand customer needs and the respective markets
- To practice and optimize successful communication with and towards existing and future customers (e.g., strategic selling, key account management, communication tools)
- To understand and use different pricing techniques for technology products and services, both in B2C and B2B contexts,
- To select appropriate strategies to build up effective sales channels and calculate and optimize respective funnel KPIs and assess the implications on the venture's business model and organization (e.g., lead management, funnel metrics, etc.)

### Content
This module exposes participants to important customer development and market research strategies, with the goal to build competencies in several customer- facing activity domains of the growing venture. Key module themes span the pricing of technology products and services, both in B2C and B2B contexts, the effective build-up of sales channels and funnels, and the successful communication to existing as well as future customers.

### Lecture notes
See Online Platform

### Literature
See Online Platform

---

This module is only for CAS ELTV Participants only.

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### Business & Leadership Development

- **Number**: 373-0200-00L
- **Title**: Business Development of Technology Ventures I
- **Type**: O
- **ECTS**: 2 credits
- **Hours**: 2P
- **Lecturers**: B. Clarysse

This module is the first part of the Business Coaching track of the CAS ELTV. The module offers a structured process through which participants develop their business projects. All projects receive regular guidance from a dedicated coach.

### Objective
This module enables participants:
- To identify key unknowns and important progress measures for their respective business case and implement effective means and tools to further develop their business case
- To understand the view of potential customers and implement their feedback to improve the business case
- To effectively communicate and enroll other important venture constituents (mentors, advisors, employees, investors, etc.) in the venture
This module focuses on the development needs of participants' business skills and competencies. In this module, experienced business coaches and startup mentors will interact regularly with the participants, offer guidance on how to strategize and implement compelling business cases, feedback on specific challenges, and participants' activities with the goal to strengthen the ability of the participant to garner needed resources for their undertakings.

Lecture notes  See Online Platform
Literature  See Online Platform
Prerequisites / notice  This module is only for CAS ELTV participants.

<table>
<thead>
<tr>
<th>373-0201-00L</th>
<th>Leadership Development I</th>
<th>O</th>
<th>1 credit</th>
<th>1P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This is the first module of the Leadership Development &amp; Coaching track of the CAS ELTV. In this module, participants take stock of their current situation and goals and develop specific action points. This process is supported by experienced leadership coaches.</td>
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<tr>
<td>Objective</td>
<td>This module enables participants:</td>
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<tr>
<td></td>
<td>- To identify current gaps in the personal management skills and competencies and develop meaningful goals and plans to fill those gaps</td>
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<td></td>
<td>- To implement effective exercises and practices to improve the participants' leadership capacity</td>
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<td></td>
<td>- To effectively communicate and manage key constituents, notably employees and key advisors in a venture project</td>
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<tr>
<td>Content</td>
<td>This module focuses on the development needs of participants' leadership competencies. In this module, experienced leadership coaches will interact regularly with the participants, coach them along a personal development plan, and feedback participants on specific challenges and activities with the goal to strengthen the participants' leadership capability and people skills.</td>
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<tr>
<td>Lecture notes</td>
<td>See Online Platform</td>
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<tr>
<td>Literature</td>
<td>See Online Platform</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This module is only for CAS ELTV participants.</td>
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<table>
<thead>
<tr>
<th>373-0205-00L</th>
<th>Final Business Project Defense</th>
<th>O</th>
<th>1 credit</th>
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</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This module focuses on the development needs for both the participants' presentation and resource mobilization skills. The participants are asked to bring all learnings from the CAS and defend in engaging manner their business projects. This defense is typically delivered in presence of external investors or venture stakeholders who will challenge the project and potentially offer future support.</td>
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<tr>
<td>Objective</td>
<td>This module enables participants:</td>
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<td></td>
<td>- To reflect upon and integrate important and relevant elements from the CAS into the venture project</td>
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<td>- To practice effective business communication and venture pitching skills</td>
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<td></td>
<td>- To receive and handle challenging feedback from important venture constituents.</td>
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<tr>
<td>Content</td>
<td>This module focuses on the development needs of participants' business skills and competencies. In this module, experienced business coaches will interact regularly with the participants, offer guidance on how to strategize and implement compelling business cases, feedback on specific challenges, and participants' activities with the goal to strengthen the ability of the participant to garner needed resources for their undertakings.</td>
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<td>Lecture notes</td>
<td>See Online Platform</td>
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<tr>
<td>Literature</td>
<td>See Online Platform</td>
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► Skills & Ecosystem Immersion

Courses are only offered in Spring Semester.

**CAS in Entrepreneurial Leadership in Technology Ventures - Key for Type**

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

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<tr>
<td>lecture</td>
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<td>practical/laboratory course</td>
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**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## CAS in Development and Cooperation

*Take place each spring semester and every second autumn semester (odd years).*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>865-0065-00L</td>
<td>VET between Poverty Alleviation and Economic Development</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>K. Hartgen, F. Kehl, M. Maurer</td>
</tr>
<tr>
<td></td>
<td>Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation.</td>
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<td></td>
<td>ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.</td>
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</tbody>
</table>

**Registration only through the NADEL administration office.**

**Abstract**
The course aims at strengthening the capacity in portfolio management for VET, skills development and active labor market policies. It deals with basic issues and challenges of Vocational Education and Training (VET) in Developing Countries. In view of the many of school leavers VET has to place itself between the contradicting intensions of quality education and short-term training interventions.

**Objective**
The participants are able to:
- Assess project proposals and ongoing project regarding their relevance and suitability in the specific country context
- Explain strengths and weaknesses of the opposing approaches "dual apprenticeship" and "competency based training" as well as synergies and incompatibilities between the two
- Describe the competent use of tools currently applied in VET

**Content**
- Basic concepts and terms
- Differences and commonalities between VET and neighboring systems
- Planning, assessment of VET interventions with different objectives: economic development, poverty alleviation, creation of self-employment or systems development
- VET as a cooperation system of stakeholders with different duties, interests and competencies
- Background, potential use and limitations of (national) qualification frameworks
- Half-day visit to important actors of the Swiss VET landscape

**Prerequisites / notice**
Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with NADEL secretariate.

<table>
<thead>
<tr>
<th>865-0000-01L</th>
<th>Planning and Monitoring of Projects</th>
<th>O</th>
<th>2 credits</th>
<th>3G</th>
<th>K. Schneider</th>
</tr>
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<tbody>
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**Registration only through the NADEL administration office.**

**Abstract**
The course provides a deeper understanding of the methodological foundations of results-oriented planning and steering of development projects. Together with the participants, we reflect on the situation-specific application of instruments for project planning and the development of a monitoring system, which makes it possible to adapt and steer projects.

**Objective**
The course participants are able to describe the processes and concepts of project planning and monitoring using the correct technical terminology, to initiate an analysis of the initial situation, to elaborate a monitoring system, and to adaptively steer the implementation of projects.

**Content**
- Basic concepts of result-oriented project management
- Instruments and resources for project planning, including the elaboration of a "logframe matrix" and results chain
- Instruments and resources for project monitoring, and for the development of a monitoring system, including indicators to assess objectives achievement and steer the Project
- 'Write' and structure results-oriented Project reports

**Prerequisites / notice**
Students of the course must fulfill requirements specified on the homepage of NADEL.

<table>
<thead>
<tr>
<th>865-0000-06L</th>
<th>Impact Evaluations in Practice</th>
<th>W</th>
<th>2 credits</th>
<th>3G</th>
<th>I. Günther, A. Rom, K. Schneider</th>
</tr>
</thead>
<tbody>
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**Registration only through the NADEL administration office.**

**Abstract**
The course gives an introduction to the most important methods for rigorous impact analysis of development programs and projects. The course is designed to both cover the most fundamental methods of impact analysis and introduce real world case studies from national, international and non-governmental development organizations and asks how rigorous impact analysis has influenced their policies.

**Objective**
Participants understand the most important methods of impact analysis. They are able to conduct small scale studies to evaluate the impact of their own programs as well as manage larger impact evaluations for their organizations. Participants are able to use the results of own and external impact studies.

**Content**
- Introduction to rigorous impact analysis; Case studies and their policy implications; Introduction to the required statistical knowledge; Potentials and limitations of quantitative analysis; Experimental and quasi-experimental methods; Relevant and feasible indicators for the measurement of outcomes and impacts; Data collection and analysis; Project management of an impact analysis.

**Prerequisites / notice**
Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with NADEL secretariate.

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</table>

Leveraging Private Impact Investors in Development Cooperation

This two-day course demystifies impact investing for people working in development cooperation. The course provides an introduction to the political economy of the Corporate Social Responsibility discourse, voluntary governance and the role of social entrepreneurship. The course conveys basic knowledge of methods and instruments for the financial management and the economic analysis of development projects. Students of the course must fulfill requirements specified on the homepage of NADEL.

Abstract

This course seeks to increase the participants' understanding of the multifaceted and dialectic relationships between civil society, governments and private sector. It equips participants with knowledge and tools required for a strategic interaction between private sector organizations and development agencies. The course enables participants to contribute effectively to policy debates on the role of private sector actors and development.

Objective

This course goes beyond awareness raising of personal cultural characteristics and recognizing cultural values within development concepts. It unfolds traces of colonialism and power structures in day to day live and the aid industry. It promotes searching and initiating practical examples of aid interventions and similar initiatives.

Content

- Decoloniality key terms and concepts
- Conceptions of and alternatives to development (cooperation)
- Cultural (self-) awareness, diversity
- The role of culture in aid / development cooperation
- Implications of decolonialism for aid policy making and practice

865-0064-00L

Decolonizing Aid

Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation. Doctoral students dealing with empirical research in the area of development and cooperation (EZA) may be admitted "sur Dossier".

Registration only through the NADEL administration office.

865-0070-00L

The Private Sector and Development Organizations: Building Successful Alliances

Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation. Doctoral students dealing with empirical research in the area of development and cooperation (EZA) may be admitted "sur Dossier".

Registration only through the NADEL administration office.

865-0021-00L

Fraud and Corruption: Prevent, Detect, Investigate, Sanction

Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation. ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.

865-0006-00L

Leveraging Private Impact Investors in Development Cooperation

Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation. Doctoral students dealing with empirical research in the area of development and cooperation (EZA) may be admitted "sur Dossier".

Registration only through the NADEL administration office.

Abstract

Students of the course must fulfill requirements specified on the homepage of NADEL.
Objective
This two-day course demystifies impact investing for people working in development cooperation. Impact investing—the idea that it is possible to “do good” as well as make money with certain types of investment—is changing the landscape of development cooperation. Impact investing is growing rapidly and development agencies and non-governmental organizations increasingly seek to leverage private investor resources. But many development actors are not accustomed to working with private investors, and are uneasy about their profit motivation and modes of operation. The course provides an introduction to the terminology and instruments involved in impact investing and evaluates developmental opportunities and trade-offs.

Content
Key topics
- Defining impact investing and understanding its importance for development
- Different types of impact investor and their incentives
- Overview of instruments such as loans, equity investments, syndication and impact bonds
- How to define and measure “impact”
- Techniques used by development agencies to leverage private investor resources
- Considering what impact investing can and cannot achieve for development goals

865-0041-00L Natural Resource Governance and Development: W 3 credits 3S F. Brugger, further speakers
Policies and Practice
Only for CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation.

ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.

Registration only through the NADEL administration office.

Abstract
First introductory, online phase of an advanced-level multi-stakeholder course with the main goal to introduce analytical tools of political economy to enhance understanding of the crucial impact of politics and power on policy outcomes.

Objective
The first phase of the course will be introductory, allowing participants to start interacting with their peers, access videos and other materials as well as engage in scheduled live sessions to refresh their knowledge and skills.

Content
Topics covered:
• Discovery and allocation of resource rights
• The political economy of natural resource extraction
• Fiscal regimes and taxation
• Managing natural resource revenues and investment
• State Owned Companies governance
• Environmental and social impacts of extraction
• Corruption and accountability

Prerequisites / notice
• Live Lecture September 27 2pm CET
• Live Lecture September 28 2pm CET
• 29 Sept - 31 Oct Self-study phase (without live lectures).
• Nov 8 - Nov 19 Live Phase (each live lecture 2pm CET and additional program sessions in the morning and/or afternoon CET).

CAS in Development and Cooperation - Key for Type
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Key for Type</th>
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</thead>
<tbody>
<tr>
<td>V lecture</td>
<td>E- Recommended, not eligible for credits</td>
</tr>
<tr>
<td>G lecture with exercise</td>
<td>Z Courses outside the curriculum</td>
</tr>
<tr>
<td>U exercise</td>
<td>Dr Suitable for doctorate</td>
</tr>
<tr>
<td>S seminar</td>
<td>W+ Eligible for credits and recommended</td>
</tr>
<tr>
<td>K colloquium</td>
<td>W Eligible for credits</td>
</tr>
<tr>
<td>P practical/laboratory course</td>
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<td>A independent project</td>
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<tr>
<td>D diploma thesis</td>
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<tr>
<td>R revision course / private study</td>
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</table>

Key for Hours

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
## CAS in Computer Science

### Focus Courses and Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
<tr>
<td></td>
<td>Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection.</td>
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<tr>
<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>After this course, students will:</td>
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<td></td>
<td>Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features. Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs. Be able to learn new languages more rapidly. Be aware of many subtle problems of object-oriented programming and know how to avoid them.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.</td>
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<td></td>
<td>The topics discussed in the course include among others:</td>
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<td>The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)</td>
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<td>The key problems of single and multiple inheritance and how different languages address them</td>
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<td>Generic type systems, in particular, Java generics, C# generics, and C++ templates</td>
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<td>The situations in which object-oriented programming does not provide encapsulation, and how to avoid them</td>
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<td>The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing</td>
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<td></td>
<td>How to maintain the consistency of data structures</td>
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<td>Literature</td>
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<td>Will be announced in the lecture.</td>
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<td>Prerequisites / notice</td>
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<td>Prerequisites: Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience</td>
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<tr>
<td>252-0293-00L</td>
<td>Wireless Networking and Mobile Computing</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>S. Mangold</td>
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<td>This course gives an overview about wireless standards and summarizes the state of the art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, including new topics such as contact tracing with Bluetooth, audio communication, cognitive radio, visible light communications. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool.</td>
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<td>The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication.</td>
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<td>Content</td>
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<td>New: Starting 2020, we will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth.</td>
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<td>Lecture notes</td>
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<td>The course material will be made available by the lecturer.</td>
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<td>Literature</td>
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<td>(1) The course webpage (look for Stefan Mangold's site)</td>
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<td>(2) The Java 802 protocol emulator “JEmula802” from <a href="https://bitbucket.org/lfield/jemula802">https://bitbucket.org/lfield/jemula802</a></td>
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<td>Prerequisites / notice</td>
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<td>Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).</td>
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<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>A. Steger</td>
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<td>Las Vegas &amp; Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks.</td>
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<td>After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.</td>
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<td>Randomized Algorithms are algorithms that &quot;flip coins&quot; to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.</td>
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<td>Lecture notes</td>
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<td>252-0463-00L</td>
<td>Security Engineering</td>
<td>W</td>
<td>7</td>
<td>2V+2U+2A</td>
<td>S. Kristic</td>
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<td>Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements &amp; risk analysis, system modeling &amp; model-based development methods, implementation-level security, and evaluation criteria for secure systems.</td>
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Autumn Semester 2021
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Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
   - "Risk": assets, threats, vulnerabilities, risk
   - Risk assessment: quantitative and qualitative
   - Safeguards
   - Generic risk analysis procedure
   - The OCTAVE approach
   - Example of qualitative risk assessment
11. Threat modeling
   - Overview
   - Safety engineering basics: FMEA and FTA
   - Security impact analysis in the design phase
   - Modeling security threats: attack trees
   - Examples and experience
12. Evaluation criteria
   - NIST special papers
   - ISO/IEC 27000
   - Common criteria
   - BSI baseline protection
13. Guest lecture
   - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
- Prerequisite: Class on Information Security
Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics, and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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**252-0543-01L Computer Graphics**

**W** 8 credits 3V+2U+2A

Does not take place this semester.

Abstract

This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.

Objective

At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students’ curiosity to explore the field of computer graphics in subsequent courses or on their own.

Content

This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature

Books:

- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in computer vision
- Physically Based Rendering: From Theory to Implementation

Prerequisites / notice

Prerequisites:

- Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, Visual Computing course recommended.

The programming assignments will be in C++. This will not be taught in the class.

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**252-0546-00L Physically-Based Simulation in Computer Graphics**

**W** 5 credits 2V+1U+1A

V. da Costa de Azevedo, B. Solenthaler, B. Thomaszewski

Abstract

This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective

This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content

The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice

Prerequisites:

- Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

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**252-1407-00L Algorithmic Game Theory**

**W** 7 credits 3V+2U+1A

P. Penna

Abstract

Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.

Objective

Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.
Content
The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don’t care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

Outline:
- Introduction to classic game-theoretic concepts.
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity.
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization.
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the 'Price of Anarchy').
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium.
- Selected current research topics, such as Google’s Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

Lecture notes
Lecture notes will be posted on the website shortly after each lecture.

Prerequisites / notice
Several copies of both books are available in the Computer Science library.

Audience: Although this is a Computer Science course, we encourage the participation from all students who are interested in this topic.

Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

252-1411-00L Security of Wireless Networks W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen
Abstract
Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.

Objective
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

Content

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, A. Perrig
Abstract
The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers individual system's aspects starting with tamperproof or tamperresistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

252-1425-00L Geometry: Combinatorics and Algorithms W 8 credits 3V+2U+2A B. Gärtner, E. Welzl, M. Hoffmann, M. Wettstein
Abstract
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

Objective
The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Content
Planar and geometric graphs, embeddings and their representation (Whitney’s Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in Rd, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chazan’s Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes
yes

Literature

Prerequisites / notice
Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

252-3005-00L Natural Language Processing W 5 credits 2V+2U+1A R. Cotterell
Number of participants limited to 400.
The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate
Reliable and Trustworthy Artificial Intelligence
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has
Computer Architecture
We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major
W
Design of Parallel and High-Performance Computing
Number of participants limited to 125.
Advanced topics in parallel and high-performance computing.
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as
Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent,
and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g.,
For solving assignments, some programming experience in Python is expected.
Big Data
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has
The video recordings of the lectures are expected to be made available after lectures.
Prerequisites / notice
Literature
We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major
Prerequisites / notice
Literature
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Literature
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This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course. Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  
  Advanced Machine Learning  
  https://ml2.inf.ethz.ch/courses/aml/  
  Computational Intelligence Lab  
  http://da.inf.ethz.ch/teaching/2019/CIL/  
  Introduction to Machine Learning  
  https://las.inf.ethz.ch/teaching/introml-S19  
  Statistical Learning Theory  
  http://ml2.inf.ethz.ch/courses/slt/  
  Computational Statistics  
  https://stat.ethz.ch/lectures/sis19/comp-stats.php  
  Probabilistic Artificial Intelligence  
  https://las.inf.ethz.ch/teaching/pai-f18

263-3845-00L  Data Management Systems  
W  8 credits  3V+1U+3A  G. Alonso

Abstract  The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective  The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content  The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature  The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

Prerequisites / notice  The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Taught competencies  Domain A - Subject-specific Competencies  Concepts and Theories assessed  Techniques and Technologies assessed

263-3840-00L  Informal Methods  
W  5 credits  2G+2A  D. Cock

Abstract  Formal methods are increasingly a key part of the methodological toolkit of systems programmers - those writing operating systems, databases, and distributed systems. This course is about how to apply concepts, techniques, and principles from formal methods to such software systems, and how to get into the habit of thinking formally about systems design even when writing low-level C Code.

Objective  This course is about equipping students whose focus is systems with the insights and conceptual tools provided by formal methods, and thereby enabling them to become better systems programmers.

Content  By the end of the course, students should be able to seamlessly integrate basic concepts form formal methods into how they conceive, design, implement, reason about, and debug computer systems.

The goal is not to provide a comprehensive introduction to formal methods - this is well covered by other courses in the department. Instead, it is intended to provide students in computer systems (who may or may not have existing background knowledge of formal methods) with a basis for applying formal methods in their work.

This course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written both by students taking the course, and practical systems developed using formal techniques, in particular the verified seL4 microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).

263-4500-00L  Advanced Algorithms  
W  9 credits  3V+2U+3A  M. Ghaffari, G. Zuzic

Abstract  This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

Objective  This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

Content  The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

Lecture notes  https://people.inf.ethz.ch/gmohsen/A221/

Prerequisites / notice  This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations, E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

**Objective**
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

**Content**
The course will cover topics spanning four broad themes with a focus on the first two themes:
1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.
Foundations of Reinforcement Learning

Abstract

Reinforcement learning (RL) has been in the limelight of many recent breakthroughs in artificial intelligence. This course focuses on theoretical and algorithmic foundations of reinforcement learning, through the lens of optimization, modern approximation, and learning theory. The course targets M.S. students with strong research interests in reinforcement learning, optimization, and control.

Objective

This course aims to provide students with an advanced introduction to RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, students will be able to
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover "new" applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

Content

Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

Lecture notes

Lecture notes will be posted on Moodle.

Literature

Dynamic Programming and Optimal Control, Vol I & II, Dimitris Bertsekas
Algorithms for Reinforcement Learning, Csaba Czepevsári

Prerequisites / notice

Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

263-5902-00L

Computer Vision

Abstract

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve these.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice

- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

263-5905-00L

Mixed Reality

Abstract

The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective

After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision(graphics/HMI) research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites / notice

Prerequisites include:
- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

636-0007-00L

Computational Systems Biology

Abstract

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational approaches to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts’ properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes

http://www.csb.ethz.ch/education/lectures.html

Methodologies to analyze the cases and create final presentations. Short overview of each case.

The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Current Topics in Information Security

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

* epidemiology
* pathogen evolution
* macroevolution of species

Content

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speculation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes

Lecture slides will be available on moodle.

Literature

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSEE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place at D-BSEE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date

http://www.cbb.ethz.ch/news-events.html

For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&aansicht=KATALOGDATEN&lerneinheitId=123546&lang=d e, or working through the script provided as part of this R course.

Seminars

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<th>Number</th>
<th>Title</th>
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<tr>
<td>252-3811-00L</td>
<td>Case Studies from Practice Seminar</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>M. Brandis</td>
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The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Participants will learn how to analyze and solve IT problems in practice in a systematic way, present findings to decision bodies, and defend their conclusions.

Objective

Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

Content

Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to company representatives, the lecturer, and all other participants of the seminar. Participants also learn how to challenge presentations from other teams, and obtain an overview of learnings from the cases other teams worked on.

Lecture notes

Successful completion of Lecture "Case Studies from Practice".

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<th>Number</th>
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<tr>
<td>252-4601-00L</td>
<td>Current Topics in Information Security</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Capkun, K. Paterson, A. Perrig, S. Shinde</td>
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</table>

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

The seminar covers various topics in information security: security protocols (models, specification & verification), trust management, access control, non-interference, side-channel attacks, identity-based cryptography, host-based attack detection, anomaly detection in backbone networks, key-management for sensor networks.

Abstract

The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

Objective
Content
The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

Selected Topics
- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

Literature
The reading list will be published on the course web site.

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<th>Course Code</th>
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<th>Prerequisites / notice</th>
<th>Literature</th>
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<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning</td>
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<td>The deadline for deregistering expires at the end of the fourth week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.</td>
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<td>The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.</td>
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<td>252-5701-00L</td>
<td>Advanced Topics in Computer Graphics and Vision</td>
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<td>This seminar covers advanced topics in computer graphics, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.</td>
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<td>Number of participants limited to 24.</td>
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<td>This seminar covers advanced topics in computer graphics, including both seminal research papers as well as the latest research results. Each time the course is offered, a collection of research papers are selected covering topics such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each student presents one paper to the class and leads a discussion about the paper and related topics. All students read the papers and participate in the discussion.</td>
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<tr>
<td>263-2100-00L</td>
<td>Research Topics in Software Engineering</td>
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<td>This seminar is an opportunity to become familiar with current research in software engineering and more generally with the methods and challenges of scientific research.</td>
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<td>This seminar is an opportunity to become familiar with current research in software engineering and more generally with the methods and challenges of scientific research.</td>
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<td>263-3504-00L</td>
<td>Hardware Acceleration for Data Processing</td>
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<td>The publications to be presented will be announced on the seminar home page at least one week before the first session.</td>
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Objective
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Content
The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, high performance computing, data appliances, and data centers.

Prerequisites / notice
Students taking this seminar should have the necessary background in systems and low level programming.

263-5156-00L Beyond iid Learning: Causality, Dynamics, and Interactions
Number of participants limited to 60.
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
Many machine learning problems go beyond supervised learning on independent data points and require an understanding of the underlying causal mechanisms, the interactions between the learning algorithms and their environment, and adaptation to temporal changes. The course highlights some of these challenges and relates them to state-of-the-art research.

Objective
The goal of this seminar is to gain experience with machine learning research and foster interdisciplinary thinking.

Content
The seminar will be divided into two parts. The first part summarizes the basics of statistical learning theory, game theory, causal inference, and dynamical systems in four lectures. This sets the stage for the second part, where distinguished speakers will present selected aspects in greater detail and link them to their current research.

Keywords: Causal inference, adaptive decision-making, reinforcement learning, game theory, meta learning, interactions with humans.

263-3713-00L Advanced Topics in Human-Centric Computer Vision
Numbers of participants limited to 20.
The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
In this seminar we will discuss state-of-the-art literature on human-centric computer vision topics including but not limited to human pose estimation, hand and eye-gaze estimation as well as generative modelling of detailed human activities.

Objective
The learning objective is to analyze selected research papers published at top computer vision and machine learning venues. A key focus will be placed on identifying and discussing open problems and novel solutions in this space. The seminar will achieve this via several components: reading papers, technical presentations, writing analysis and critique summaries, class discussions, and exploration of potential research topics.

Content
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.

Reviewer: Perform a critical review of the paper.

Prerequisites / notice
All other students: read the paper and submit questions they have about the paper before the presentation.
Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Taught competencies
Domain B - Method-specific Competencies
Analytical Competencies assessed
Domain C - Social Competencies
Communication assessed
Domain D - Personal Competencies
Critical Thinking assessed

CAS in Computer Science - Key for Type
O Compulsory E- Recommended, not eligible for credits
W+ Eligible for credits and recommended Z Courses outside the curriculum
W Eligible for credits Dr Suitable for doctorate

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

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
The CAS is offered once per year in the spring semester.
Course duration: 1 Semester, part-time

More information at: www.sspg.ethz.ch/en

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<th>CAS in International Policy and Advocacy - Key for Type</th>
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ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Future Transport Systems: New Business Models

The "CAS in Future Transport Systems: New Business Models" takes place only in Spring Semester

Start of the next course: Spring Semester 2022
Course duration: Six months part time
Periodicity: Every two years


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ECTS - European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Future Transport Systems: Systemic Aspects of Future Transport

The "CAS in Future Transport Systems: Systemic Aspects of Future Transport" takes place only in Spring Semester

Start of the next course: Spring Semester 2023
Course duration: Six months part time
Periodicity: Every two years


CAS in Future Transport Systems: Systemic Aspects of Future Transport - Key for Type

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ECTS  European Credit Transfer and Accumulation System
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The digital revolution, spatial information and communication systems in particular, have a significant influence on the development of new

Familiarity with conventional and alternative powertrain and automotive systems for future sustainable mobility, and the ability to identify and deploy their potential to address concrete problems.

Familiarity with information and communication technologies (ICT) and spatial information technologies, and the ability to identify and utilise their potential to address concrete problems.

The module provides a foundation in the current situation and short- and mid-term development directions of powertrain and automotive engineering in the context of passenger & goods transport. Corresponding energy sources and resulting consequences for the energy system are addressed. Participants will be enabled to identify potentials of these technologies and apply them to concrete problems.

Familiarity with information and communication technologies (ICT) and spatial information technologies, and the ability to identify and utilise their potential to address concrete problems.

Overview of suitable methods for analysing and evaluating technical systems (transport systems) and the ability to choose among them to address concrete problems.

The digital revolution, spatial information and communication systems in particular, have a significant influence on the development of new transport systems. Participants acquire an in-depth understanding of the functionality and application potential of spatial information systems and services and of communication technologies for deployment in future transport systems and applications.

Overview of concepts and implementation methods

Analyses based upon energy-economic models which explicitly represent transport and energy-supply technologies. It also presents scenario analyses based upon energy-economic models which explicitly represent transport and energy-supply technologies.

Announced to students of the of the MAS / CAS at the beginning of the term.

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An overview of suitable methods for analysing and evaluating technical systems (transport systems) and the ability to choose among them to address concrete problems.

Selected methods for assessing transport technologies and their application to current and future options

Introduction to and overview of integrated assessment

Current status of transport in Switzerland and internationally

Scope and goals of integrated assessment

Sustainability: concept and practical implementation via criteria and indicators

Overview of concepts and implementation methods

Overview of concepts and implementation methods

Overall costs (internal and external)

Multi-criteria analysis

(4) Analysis of transport scenarios

Scenarios, influencing factors, policy and sustainability

Approaches to scenario modelling

Global mobility scenarios: examples

Transport scenarios for Switzerland using energy system models
Abstract
The module includes the supply of the road mobility of the future with renewable energy. The generation, transport, processing, transfer of energy to the vehicles (refueling, charging) and the energetic evaluation are presented. Electricity, hydrogen, biogenic and synthetic fuels are considered.

Objective
The aim of the module is a detailed energetic and technical understanding of the supply of road vehicles with renewable energy. Graduates know the primary energy production as well as the end energy processing of the different energy carrier concepts. In addition, they know the legal CO2 requirements for vehicle registration and are able to qualitatively assess the impact on the Swiss energy system.

Content
- The energy system of the future; biogenic and electric renewable primary energy
- End energy processing
- Transfer from the energy system to mobility and influences on the overall energy system

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS / CAS at the beginning of the term

CAS Thesis

Number 166-0290-00L
Title CAS Thesis on Technology Potentials
Type O
ECTS 3 credits
Hours 5D
Lecturers M. A. Streicher-Porte

Abstract
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS Technology Potentials.

Objective
- Deal with a specific problem from the CAS Technology Potentials subject area.
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS / CAS at the beginning of the term

CAS in Future Transport Systems: Technology Potential - Key for Type

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ECTS European Credit Transfer and Accumulation System

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## CAS in Nutrition for Disease Prevention and Health - Key for Type

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## CAS in Nutrition for Disease Prevention and Health - Key for ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
## Modules

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<td>R. Schibli</td>
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*Does not take place this semester. Only for CAS in Pharmaceuticals.*

*The enrolment is done by the CAS in Pharmaceuticals study administration.*

### Abstract

Pharma Project Management and Communication

### Objective

Project Management Basics:
- About projects, project management and the project environment
- How to define and plan my project, how to deal with stakeholders and how to manage project risks
- Managing my project team, developing the project plan and launching the project
- Managing my project team, developing the project plan and launching the project
- Monitoring and reporting, project close-out and project leadership
- Project evaluation and portfolio management
- Budget and resource management

**Workshop:**
- Development of a generic drug product in cross-functional project teams

**Communication:**
- Intercultural communication
- Negotiation skills
- Presentation power

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*Only for CAS in Pharmaceuticals.*

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### Abstract

Module 7 gives an overview about the several steps that have to be followed during the process of clinical development.

### Objective

- Preclinical bridge to clinical development
- Strategy for clinical development
- Regulatory aspects of clinical development
- Good clinical practice (GCP) and quality assurance
- First in human studies (Phase I), Proof of concept studies (Phase II), Registration studies (Phase III), Post-registration studies (Phase IV)
- Monitoring
- Organizational and financial aspects of clinical development
- Portfolio and life cycle management
- Data management and simulation of a clinical study
- Personalized medicine

## Essay

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*Only for CAS in Pharmaceuticals.*

*The enrolment is done by the CAS in Pharmaceuticals study administration.*

### Abstract

The essay is an essential part of the CAS program „Pharmaceuticals – From Research to Market“ (CAS Pharm) and serves as final performance assessment.

### Objective

The essay documents the student’s competence development during the program as well as the transfer of acquired knowledge to professional practice/activities.

### Literature

[www.postgraduate.pharma.ethz.ch](http://www.postgraduate.pharma.ethz.ch) documents: essay

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**CAS in Pharmaceuticals - From Research to Market - Key for Type**

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ECTS **European Credit Transfer and Accumulation System**

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CAS Thesis

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<td>M. Ambühl, N. Meier</td>
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Abstract
In their CAS thesis, participants synthesize their learning and apply their insights to their own institutions or examine a relevant topic employing the course methodologies.

Objective
Practical application of course content and concepts.

CAS in Public Governance and Administration - Key for Type

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**Abstract**

Module I:
- Knowledge of the fundamentals of development, preparation, testing and stability of sterile radiopharmaceutical preparations.
- Acquisition of basic information on European legislation in Radiopharmacy including GMP and Pharmacopoeia.
- Understanding basics of gene engineering and pharmacokinetics.

**Objective**

- Good manufacturing practice (GMP) of classical radiopharmaceuticals
- Molecular and cellular aspects of radiobiology
- Pharmacopoeia
- Pharmacopoeia – how to use it
- Design of dosage forms for pharmaceuticals
- Pharmaceutical packaging
- Methods of preparation of sterile products
- Aseptic preparation
- The role of excipients in parenteral radiopharmaceutical preparations
- Sterility testing and endotoxin determination
- Particulate contamination
- Principles of medicinal chemistry
- An overview of modern pharmaceutical analysis
- Genetic engineering
- Stability and shelf-life of pharmaceuticals
- (in)stability of radiopharmaceuticals
- Legislation in radiopharmacy
- European directives – GMP
- Specific radiopharmaceutical legislation
- Clinical trials directive and related documents
- The small scale, non-commercial preparation of radiopharmaceuticals
- GMP of PET radiopharmaceuticals
- Quality assurance and preparation of SOP
- Water for pharmaceutical use
- Practicals: visit to hospital radiopharmacy
- Basic concepts of pharmacokinetics
- Drug regulatory affairs
- Microbiology in Pharmacy
- Visit to pharmaceutical company

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**Abstract**

Participants will understand concepts of Pharmacology, Toxicology and Fundamentals of Nuclear Medicine

**Objective**

- Pharmacokinetics and kinetic-modelling
- Statistics and practical session
- Radiotracers in biochemistry and molecular pharmacology
- Selective modification of peptides and proteins to target GPCRs
- Demonstration of experimental set up: Peptide and protein modification, radioactive assays in biochemistry
- Visit ABX Radeberg
- Nuclear medicine: basics and therapy
- Immunology
- Drug interventions/interactions/adverse reactions
- Pharmacology basics, special aspects, clinical studies
- Toxicology
- Testsystems in toxicity and targeted therapeutics and nucleic acids
- Nuclear medicine: clinical diagnostic applications in neurology
- Nuclear medicine: visit to SPECT facility and radiopharmaceutical GMP lag (Tc, Ga, therapy)
- Radiological imaging modalities- technology and applications
- Nuclear medicine: clinical diagnostic applications in oncology
- Radiopharmaceutical monographs in the European pharmacopoeia
- Practical session, visit: cyclotron, GMP PET production and quality control, PET and PET/CT, therapy unit
- Radioligand-binding-assays/autoradiography
- In house tours in groups: radioligand-binding-assays, autoradiography, metabolite analytics with LC-MS, cyclotron and radiochemistry, highlights in Leipzig
- Biological effects of radiation
- Radiotracer transport and blood brain barrier
- Radiotracers for neuroimaging

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**CAS in Radiopharmaceutical Chemistry, Radiopharmacy - Key for Type**

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### ECTS
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<td>The preliminary course introduces students to the</td>
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<td>Methods, tools and processes in large scale landscape</td>
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<td>architectural design. On the basis of a case study, «Basel»</td>
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<td>approaches of landscape on a large scale, with the aim</td>
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<td>and take their own position.</td>
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<td>and environmental planning; comprehending landscape</td>
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<td>as well as essential theories; insights in planning</td>
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<td>Current and future significant tasks of Spatial Planning</td>
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<td>in Switzerland. In addition to the existing inner</td>
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<td>development of settlements, the importance of new</td>
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<td>challenges such as climate adaptation and the</td>
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<td>implementation of the mobility turn is rising. What they</td>
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<td>have in common is the need of methods and instruments for</td>
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<td>exploring, clarifying and solving complex tasks.</td>
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<td>The aim of the course is the acquaintance and the</td>
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<td>spatial planning in Switzerland and to discuss them in</td>
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<td>the light of future challenges. In particular, the</td>
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<td>methodological modules of the course form an essential</td>
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<td>Starting point of the course are existing and future</td>
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<td>spatially significant tasks. In addition to the</td>
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<td>presentation and description of typical challenges using</td>
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<td>case studies, the focus is also on the understanding of</td>
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<td>context and relationships as well as constants and</td>
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<td>variables of spatial development. Different types of</td>
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<td>tasks and the resulting consequences for their</td>
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<td>clarification and solution are also discussed.</td>
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<td>The tasks are contrasted with a brief overview of</td>
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<td>existing spatial planning instruments in Switzerland.</td>
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<td>On the one hand, the aim is to develop a common</td>
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<td>understanding of the formal and informal procedures and</td>
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<td>instruments of spatial planning; on the other hand, these</td>
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<td>are also to be discussed with regard to their</td>
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<td>effectiveness for current and future challenges.</td>
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<td>At the centre of the teaching unit is the teaching</td>
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<td>and methodological basis for exploring, clarifying and</td>
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<td>solving complex issues. These refer to the questions</td>
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<td>and pitfalls of perceiving and dealing with</td>
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<td>complexity, to methodological elements of processes for</td>
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<td>clarifying difficult spatially significant tasks with a</td>
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<td>large number of actors involved, as well as methods of</td>
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<td>situation assessment, design and decision-making as a</td>
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<td>basis for developing solutions.</td>
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**CAS in Spatial Planning - Key for Type**

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

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### Key for Hours

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**ECTS**
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
CAS Module in Robotics and AI

Only for CAS in Robotics.

Abstract
In the CAS Robotics participants are offered a RobotX professor as a mentor together with whom they design their study plan along an individually-specified focus area in the area of Robotics and AI. Based on the individual expertise and interests of the participants, the customised Robotics and AI module consists of a combination of (i) research project, (ii) lectures, (iii) knowledge transfer.

Objective
The CAS Robotics and AI module offers experienced industry individuals the opportunity to undergo research-related training in Robotics and AI, to update their knowledge and to expand their area of expertise in a targeted manner and aims at:
- training skills at the frontiers of the current state of research in Robotics and AI,
- deepening technical know-how with state-of-the-art knowledge in the specified focus area, and
- advancing practical competencies in the impart of expertise and knowledge transfer across disciplines and educational levels.

Key for Hours

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ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
CAS in Seismic Evaluation and Retrofitting
Offered only in the Autumn Semester.

Module

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Abstract
The objective of this Module is to introduce the principles of Seismic Design of Structures and the Swiss Seismic Code Provisions to Civil Engineers working in Switzerland.

Objective
This module enables participants:
- To understand the critical points of the Swiss Code Provisions for the seismic design of new structures and the seismic evaluation of existing structures
- To get an overview in the dynamics and the principles of seismic design of structures

Content
1.1 Introduction to seismic hazard and seismic risk, seismic performance objectives, common structural deficiencies and observed damage patterns due to earthquake ground motion excitation
1.2 Seismic elastic and inelastic response of SDOF systems and earthquake response spectra
1.3 Seismic elastic and inelastic response of MDOF systems, Response Spectrum Analysis and Pushover Analysis
1.4 Seismic Design of structures using SIA 261: Presentation and Examples
1.5 Good practices for the seismic design of new structures
1.6 Seismic safety of non-structural components
1.7 Swiss Code Provisions for the seismic evaluation of existing structures SIA 269/8: Presentation and examples, Evaluation of commensurability of seismic retrofitting measures

Prerequisites / notice
- Anwesenheit (mind. 80% pro Präsenzwoche) und aktive Mitarbeit in den Präsenzwochen - mindestens genügende Leistungen bei Leistungskontrollen

139-0102-00L | Module 2: Finite Element Modelling and Identification of the Seismic Behavior of Structures Only for CAS in Seismic Evaluation and Retrofitting. | O      | 2 credits | 3G    | A. Tsiavos, B. Stojadinovic |

Objective
This module enables participants:
- To use the state-of-the-art FEM software and implement the optimal FE modelling techniques for the simulation of the seismic response of existing buildings (concrete, masonry, mixed concrete-masonry) located in Switzerland
- To obtain knowledge of the FEM software and the modelling techniques for the simulation of soil-structure interaction
- To understand the current methodologies for the identification and monitoring of the vibration and the seismic behavior of structures located in Switzerland.

139-0103-00L | Module 3: Analysis Methods and Case Study Examples of Seismic Evaluation and Retrofitting Only for CAS in Seismic Evaluation and Retrofitting. | O      | 2 credits | 3G    | A. Tsiavos, B. Stojadinovic |

Abstract
The scope of this Module is to present Analysis Methods and Case Study Examples that illustrate established procedures and practical engineering solutions that are applied in the seismic evaluation and retrofitting of existing structures by Civil Engineers working in Switzerland.

Objective
This module enables participants:
- To acquire practical knowledge of the seismic retrofitting techniques commonly used in Switzerland, their implementation and their cost
- To select the appropriate analysis method for the seismic evaluation of structures located in Switzerland and understanding of the governing factors

139-0104-00L | Module 4: Individual Project Exercise Only for CAS in Seismic Evaluation and Retrofitting. | O      | 4 credits | 2P    | A. Tsiavos, B. Stojadinovic |

Objective
This module enables participants:
- To conduct independently a seismic evaluation of an existing structure located in Switzerland considering the boundary conditions that influence the seismic behavior of the structure

Key for Hours

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<tr>
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<td>diploma thesis</td>
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<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## CAS in Technology and Public Policy: Impact Analysis

Offered only in Autumn Semester.

### Module

<table>
<thead>
<tr>
<th>Number</th>
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<td>(Only for CAS in Technology and Public Policy: Impact Analysis)</td>
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</table>

**Abstract**
Markets play an important function in modern societies by allocating resources and capital. Yet, important market failures require the intervention of public policy. This module introduces the fundamentals of micro- and macro-economics and thereby lays the foundation for the economic assessment of policy interventions.

**Objective**
How Markets Function (Microeconomics):
Participants (1) understand basic principles, problems and approaches in microeconomics, (2) can analyse and explain simple economic principles in a market using supply and demand graphs, (3) can contrast different market structures and describe firm and consumer behaviour, (4) can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole, (5) can address utility maximization and cost minimization problems.

How Economic Systems Function (Macroeconomics):
Participants understand (1) the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates, (2) why national economic activity fluctuates, (3) what economic policy can do against unemployment and inflation, (4) what significance international economic relations have for specific countries, such as Switzerland.

**Literature**
Course materials can be found on Moodle.

| (Only for CAS in Technology and Public Policy: Impact Analysis) | | | | | |

**Abstract**
Technologies substantially affect the way we live and how our societies function. Technological change, i.e. the innovation and diffusion of new technologies, is a fundamental driver of economic growth but can also have detrimental side effects. This module introduces methods to assess technology-related policy alternatives and to analyse how policies affect technological changes and society.

**Objective**
Introduction:
Participants understand (1) what ex ante and ex post policy impact analysis is, (2) in what forms and with what methods they can be undertaken, (3) why they are important for evidence-based policy-making.

Analysis of Policy and Technology Options:
Participants understand (1) how to perform policy analyses related to technology; (2) a policy problem and the rationale for policy intervention; (3) how to select appropriate impact categories and methods to address a policy problem through policy analysis; (4) how to assess policy alternatives, using various ex ante policy analysis methods; (5) how and to communicate the results of the analysis.

Evaluation of Policy Outcomes:
Participants understand (1) when and why policy outcomes can be evaluated based on observational or experimental methods, (2) basic methods for evaluating policy outcomes (e.g. causal inference methods and field experiments), (3) how to apply concepts and methods of policy outcome evaluation to specific cases of interest.

Big Data Approaches to Policy Analysis:
Participants understand (1) why "big data" techniques for making policy-relevant assessments and predictions are useful, and under what conditions, (2) key techniques in this area, such as procuring big datasets; pre-processing and dimension reduction of massive datasets for tractable computation; machine learning for predicting outcomes; interpreting machine learning model predictions to understand what is going on inside the black box; data visualization including interactive web apps.

**Literature**
Course materials can be found on Moodle.

| 876-0301-00L   | Policy-Making in Practice                     | O          | 4    | 3G    | T. Bernauer, D. N. Bresch, T. Schmidt |
| (Only for CAS in Technology and Public Policy: Impact Analysis) | | | | | |

**Abstract**
Effective management of risks and uncertainty as well as communication of scientific evidence to stakeholders and policy-makers are essential for successful policy-advice and policy-making. Hence, this module conveys the fundamentals of risk analysis/management and of writing for policy-makers. Besides an academic perspective, it features practitioners working at the technology-policy interface.

**Objective**
Participants understand (1) how to perform policy analyses related to technology; (2) a policy problem and the rationale for policy intervention; (3) how to apply methods of quantitative risk analysis, (4) how to communicate risk information clearly and effectively.

Writing for Policy-Makers:
Participants understand (1) particular prerequisites for successful dissemination of scientific results to policy-makers and the wider public, (2) expectations and needs of different target groups and audiences, (3) how to effectively write policy briefs for stakeholders and policy-makers.

**Literature**
Course materials can be found on Moodle.

**Key for Hours**

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

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
CAS in Transport Engineering

Module

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<td>149-0001-00L</td>
<td>Transport Planning - Theory and Models</td>
<td>O</td>
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<td>3G</td>
<td>K. W. Axhausen, M. Friedrich</td>
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<td></td>
<td>Only for CAS/DAS in Transport Engineering and MAS in Future Transport Systems</td>
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<tr>
<td>149-0002-00L</td>
<td>Traffic Engineering</td>
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CAS in Transport Engineering - Key for Type

<table>
<thead>
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<tr>
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<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
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Key for Hours

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ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Chemistry (General Courses)

#### General Courses

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<td>529-0073-00L</td>
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<td>Z</td>
<td>2 credits</td>
<td>2V</td>
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<td><em>Does not take place this semester.</em></td>
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<tr>
<td>Abstract</td>
<td>Principles and phenomena around radioactivity.</td>
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<tr>
<td>Objective</td>
<td>Knowledge of the most important phenomena in relation with radioactivity. Knowledge of the principles of radiation protection. Ability to judge dangerous situations in handling radioactive materials, geopolitically as well as locally at one's own working place.</td>
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<tr>
<td>Content</td>
<td>Structure and properties of atomic nuclei, mathematical description of the radioactive decay, decay types, interaction of radiation with matter, detectors for ionizing radiation, radiation protection, principles of isotope separation, nuclear power plants, major nuclear accidents. Additional topics may be suggested by the students.</td>
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### Chemistry (General Courses) - Key for Type

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### Chemistry (General Courses) - Key for Hours

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### Chemistry Bachelor

#### 1. Semester

##### Compulsory Subjects First Year Examinations

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<td>A. Togni</td>
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<tr>
<td></td>
<td>Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions</td>
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<td><strong>Objective</strong></td>
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<td>Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective</td>
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<td></td>
<td>Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility</td>
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<td>Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.</td>
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<td>Media and Digital Technologies</td>
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<td>Self-direction and Self-management</td>
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<td>529-0011-03L</td>
<td>General Chemistry (Organic Chemistry) I</td>
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<td>2V+1U</td>
<td>P. Chen</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.</td>
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<td><strong>Objective</strong></td>
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<td>Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.</td>
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<td><strong>Content</strong></td>
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<td>Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicality, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intermolecular interactions.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt</td>
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<td><strong>Abstract</strong></td>
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<td>Die Vorlesung vermittelt eine Einführung in einige physikalischen Grundlagen der Chemie, insbesondere in die Radioaktivität, die Quantenmechanik, den Aufbau der Materie und eines Atoms, des Periodensystems der Elemente und die chemische Bindung.</td>
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<td><strong>Objective</strong></td>
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<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.</td>
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<td><strong>Lecture notes</strong></td>
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<td>See homepage of the lecture.</td>
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</table>

Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids) Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book "Physics" by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

Domain A - Subject-specific Competencies
Concepts and Theories
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed
Decision-making
not assessed
Media and Digital Technologies
not assessed
Problem-solving
assessed
Project Management
not assessed

Domain C - Social Competencies
Communication
not assessed
Cooperation and Teamwork
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Customer Orientation
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Leadership and Responsibility
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Self-presentation and Social Influence
not assessed
Sensitivity to Diversity
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Negotiation
not assessed

Domain D - Personal Competencies
Adaptability and Flexibility
not assessed
Creative Thinking
assessed
Critical Thinking
assessed
Integrity and Work Ethics
assessed
Self-awareness and Self-reflection
assessed
Self-direction and Self-management
assessed

Prerequisites / notice
Voraussetzungen: Maturastoff. Insbesondere Integral- und Differentialrechnung.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Domain B - Method-specific Competencies
Analytical Competencies
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Decision-making
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Media and Digital Technologies
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Problem-solving
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Objective
Qualitative analysis (simple cation and anion separation process, determination of cations and anions), acid-base-equilibria (strengths of acids and bases, pH- and pKₐ-values, titrations, buffer systems, Kjeldahl determination), precipitation equilibria (gravimetry, potentiometry, conductivity), oxidation state and redox behaviour (syntheses), redox-titrations, galvanic elements, metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration) analysis of measured values (measuring error, average value, error analysis), states of aggregation (vapour pressure), characteristics of electrolytes (conductivity measurements), thermodynamics (calorimetry, solubility).

Content
The general aim for the students of the practical course in general chemistry is an introduction in the scientific work and to get familiar with some experimental procedures in a chemical laboratory. In general, first experiences with the principal reaction behaviour of a variety of different substances will be made. The chemical characteristics of these will be elucidated by a series of quantitative experiments alongside with the corresponding qualitative analyses. In order to get an overview of classes of substances as well as some general phenomena in chemistry suitable experiments have been chosen. In the second part of the practical course, i.e. physical chemistry, the behaviour of substances in their states of aggregation as well as changes of selected physical values will be recorded and discussed.

Lecture notes
http://www.gruetzmacher.etf.ethz.ch/education/labcourses

Literature
Moodle Lernplattform

Prerequisites / notice
Compulsory: online enrolment latest one week after start of the semester
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

3. Semester

Compulsory Subjects Examination Block I

<table>
<thead>
<tr>
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<tr>
<td>529-0121-00L</td>
<td>Inorganic Chemistry I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>H. Grützmacher, P. Steinegger</td>
</tr>
</tbody>
</table>

Abstract
Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals as well as the lanthanides and actinides. Introduction of methods of characterization, physical-chemical properties of coordination compounds as well as principles of radiochemistry.

Objective
The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. The students will acquire knowledge on the fundamentals of radioactive decay and radiochemistry. Furthermore, the students will be familiar with the basics of inorganic chemistry of lanthanides and actinides.

Content
This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides: 1) General definitions and terms in coordination chemistry; 2) Coordination numbers and structures; 3) Ligand types; 4) The chemical bond in coordination compounds part A: Crystal field theory and ligand field theory; 5) The chemical bond in coordination compounds part B: Qualitative MO theory; 6) Reactivity and reaction mechanisms of coordination compounds; 7) Group theory and character tables; 8) Properties and characterization of coordination compounds; 9) Introduction to radiochemistry; 10) Principles of the chemistry of the lanthanides and actinides.

Lecture notes
Eine kommentierte Foliensammlung ist im HCI-Shop erhältlich.

Literature

Taught competencies

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<td>Domain D - Personal Competencies</td>
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4 credits

529-0221-00L | Organic Chemistry I | O    | 3 credits | 2V+1U   | H. Wennemers |

Abstract
Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Objective
Acquisition of a basic repertoire of synthetic methods including important reactions of aldehydes, ketones, carboxylic acids and carboxylic acid derivatives, as well as eliminations and fragmentations. Particular emphasis is placed on the understanding of reaction mechanisms and the correlation between structure and reactivity. A deeper understanding of the concepts presented during the lecture is reached by solving the problems handed out each time and discussed one week later in the exercise class.

Content
Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Lecture notes
A pdf file of the printed lecture notes is provided online. Supplementary material may be provided online.

Literature
No set textbooks. Optional literature will be proposed at the beginning of the class and in the lecture notes.

529-0422-00L | Physical Chemistry II: Chemical Reaction Kinetics | O    | 4 credits | 3V+1U   | F. Merkt, U. Hollenstein |

Abstract

Objective
Introduction to Chemical Reaction Kinetics
Content
- Fundamental concepts: rate laws, elementary reactions and composite reactions, molecularity, reaction order.
- Experimental methods in reaction kinetics up to new developments in femtosecond kinetics.
- Simple chemical reaction rate theories: temperature dependence of the rate constant and Arrhenius equation, collision theory, reaction cross-section, transition state theory.

Literature

Prerequisites / notice
- Voraussetzungen:
  - Mathematik I und II
  - Allgemeine Chemie I und II
  - Physikalische Chemie I

529-0051-00L Analytical Chemistry I

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications.

Content
- Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:
  - Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
  - NMR spectroscopy: chemical shift, spin-spin coupling.
  - IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.

Lecture notes
- Script will be for the production price
- Literature
  - M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995
  - E. Pretsch, P. Bühlmann, C. Affolter, M. Badertscher, Spektroskopische Daten zur Strukturaufklärung organischer Verbindungen, 4.

Prerequisites / notice
- Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

401-0373-00L Mathematics III: Partial Differential Equations

Abstract

Objective
Classical tools to solve the most common linear partial differential equations.

Content
1) Examples of partial differential equations
   - Classification of PDEs
   - Superposition principle

2) One-dimensional wave equation
   - D'Alembert's formula
   - Duhamel's principle

3) Fourier series
   - Representation of piecewise continuous functions via Fourier series
   - Examples and applications

4) Separation of variables
   - Solution of wave and heat equation
   - Homogeneous and inhomogeneous boundary conditions
   - Dirichlet and Neumann boundary conditions

5) Laplace equation
   - Solution of Laplace's equation on the rectangle, disk and annulus
   - Poisson formula
   - Mean value theorem and maximum principle

6) Fourier transform
   - Derivation and definition
   - Inverse Fourier transformation and inversion formula
   - Interpretation and properties of the Fourier transform
   - Solution of the heat equation

7) Laplace transform (if time allows)
   - Definition, motivation and properties
   - Inverse Laplace transform of rational functions
   - Application to ordinary differential equations

Lecture notes
See the course web site (linked under Lernmaterialien)


Additional books:

4) E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1, 2, 11, 12, 6)

For additional sources, see the course web site (linked under Lernmaterialien)

Prerequisites / notice

1) Multivariate functions: partial derivatives, differentiability, Jacobian matrix, Jacobian determinant

2) Multiple integrals: Riemann integrals in two or three variables, change of variables

2) Sequences and series of numbers and of functions

3) Basic knowledge of ordinary differential equations

Laboratory Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0129-00L</td>
<td>Inorganic and Organic Chemistry II</td>
<td>O</td>
<td>11</td>
<td>16P</td>
<td>V. Mougel</td>
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</table>

Abstract
Introduction to the experimental methods of Inorganic Chemistry

Objective
The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compound are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Content
Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds. Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

Lecture notes
A manual is distributed in the teaching laboratory.

Prerequisites / notice
- Passed Basisprüfung
- Passed Practical Course General Chemistry (1. Semester, 529-0011-04)
- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230)
- Continuous Attendance of Course Inorg. Chemistry 1 (3. Sem., 529-0121) and Analytical Chemistry 1 (3. Sem., 529-0051)

If necessary, access priority will be settled according to the results of the first-year examinations.

Taught competencies

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

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

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

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

Compulsory Subjects Examination Block II

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0132-00L</td>
<td>Inorganic Chemistry III: Organometallic Chemistry and Homogeneous Catalysis</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>C. Copéret, A. Togni</td>
</tr>
</tbody>
</table>

Abstract
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carbonylation, C-C bond-forming and related reactions.
Objectives
Towards an understanding of the fundamental coordination-chemical and mechanistic aspects of transition-metal chemistry relevant to homogeneous catalysis.

Contents
Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative additions, reductive eliminations and insertion reactions. Catalytic hydrogenation, carboxylation, C-C bond-forming and related reactions.

Learning outcomes
- Ability to apply basic principles of diastereoselective synthesis
- Knowledge of spectroscopic methods and techniques in chemistry
- Comprehension of fundamental aspects of the organometallic chemistry of transition elements

Assessment

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<tbody>
<tr>
<td>529-0231-00L</td>
<td>Organic Chemistry III: Introduction to Asymmetric Synthesis</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>E. M. Carreira</td>
</tr>
</tbody>
</table>

Objective
Methods of Asymmetric Synthesis

Content
Understanding of the basic principles of diastereoselective synthesis

Learning outcomes
- Ability to apply basic principles of diastereoselective synthesis
- Knowledge of spectroscopic methods and techniques in chemistry
- Comprehension of fundamental aspects of the organometallic chemistry of transition elements

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<tr>
<td>529-0432-00L</td>
<td>Physical Chemistry IV: Magnetic Resonance</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>G. Jeschke, M. Ernst</td>
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</table>

Objective
Theoretical foundations of magnetic resonance (NMR, EPR) and selected applications.

Content
Introduction to magnetic resonance in isotropic and anisotropic phase.

Assessment

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<tr>
<td>529-0449-00L</td>
<td>Spectroscopy</td>
<td>O</td>
<td>13 credits</td>
<td>13P</td>
<td>E. C. Meister, B. Hattendorf</td>
</tr>
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</table>

Objective
Laboratory experiments to acquire a profound knowledge of spectroscopical methods and techniques in chemistry. Evaluation and visualization of measurement data. Writing lab reports.

Content
Laboratory experiments: UV/VIS spectroscopy, luminescence spectroscopy, FT infrared spectroscopy, light diffraction and refraction, thermal lenses, Raman spectroscopy, reflection spectroscopy, optical polarization phenomena, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), FT nuclear magnetic resonance spectroscopy (NMR), electron paramagnetic resonance spectroscopy (EPR), atomic force microscopy (AFM), Fourier transform methods.

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<tr>
<td>529-0341-00L</td>
<td>Physical Methods for Inorganic Chemistry</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>M. D. Wörle, D. Günther, J. Koch, R. Verel</td>
</tr>
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Objective
Introduction into the important methods for structural analysis (solid state NMR), crystal structure analysis and surface analysis techniques and their applications.

Assessment

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</table>
### Physical Chemistry

#### Number
529-0441-00L  

#### Title
Signal Processing

#### Type
W

#### ECTS
6 credits

#### Hours
3G

#### Lecturers
G. Jeschke, M. Yulikov

#### Abstract
Introduction of the basics of signal processing in spectroscopy. Fourier transformation, linear response theory, stochastic signals, digital data processing, Fourier spectroscopy.

#### Objective
Basics of signal processing in spectroscopy

#### Content

#### Literature
- Script available

### Analytical Chemistry

#### Number
529-0041-00L

#### Title
Modern Mass Spectrometry, Hyphenated Methods, and Chromemics

#### Type
W

#### ECTS
6 credits

#### Hours
3G

#### Lecturers
R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano

#### Abstract
Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.

#### Objective
Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.

#### Content
Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, nanoy methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).

#### Literature
- Lecture notes will be made available online.

#### Prerequisites / notice
- Prerequisites: 529-0051-00 "Analytische Chemie I (3. Semester)"  
  529-0058-00 "Analytische Chemie II (4. Semester)" (or equivalent)

#### Taught competencies
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: not assessed
  - Media and Digital Technologies: not assessed
  - Problem-solving: assessed
  - Project Management: not assessed

- Domain C - Social Competencies
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed

- Domain D - Personal Competencies
  - Adaptable and Flexibility: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed

### Biological Chemistry

#### Number
529-0731-00L

#### Title
Nucleic Acids and Carbohydrates

#### Type
W

#### ECTS
6 credits

#### Hours
3G

#### Lecturers
D. Hilvert, P. A. Kast, S. J. Sturla, H. Wennemers

#### Abstract
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

#### Objective
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

#### Content
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNA; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

#### Lecture notes
No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

#### Literature
Mainly based on original literature, a detailed list will be distributed during the lecture

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Autumn Semester 2021  
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### Domain A - Subject-specific Competencies

**Chemical Biology - Peptides**

**Objective:** Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

**Prerequisites / notice:** Students should be familiar with the fundamentals of physical chemistry.

**Literature:**

**Prerequisites / notice:**

**Taught competencies:**
- Domain A - Subject-specific Competencies: Concepts and Theories

**Lecture notes:**
- The script and exercises will be distributed weekly in loose form

**Number:** 529-0240-00L

**Title:** Chemical Biology - Peptides

**ECTS:** 6 credits

**Hours:** 3G

**Lecturers:** H. Wennemers

**Abstract:** An advanced course on the synthesis, properties and function of peptides in chemistry and biology.

**Content:**
- Introduction: important quantities & units, terminology;
- Knowledge of the synthesis, properties and function of peptides in chemistry and biology.

**Course description:**

**Concepts and Theories**


**Principles of Crystal Structure Determination**

**Objective:**

To gain an understanding of the principles of crystal structure determination by X-ray diffraction.

**Content:**

Basic crystallographic concepts: Unit cells, Bravais lattices, Laue symmetry, crystal classes (point groups), space groups, crystal growth, instrumentation, diffraction of X-rays by crystals: physical and geometric basics, powder and single crystal methods, structure solution and modelling, interpretation of crystal structure data; internal coordinates for structure description: atom spacing, co-ordination polyhedra, bond angles, torsion angles; intermolecular interactions, absolute configuration determination. Overview of inorganic, organic and macromolecular databases.

**Lecture notes:**
- The script and exercises will be distributed weekly in loose form

**Number:** 529-0039-00L

**Title:** Principles of Crystal Structure Determination

**ECTS:** 6 credits

**Hours:** 3G

**Lecturers:** M. D. Wröle, N. Trapp

**Abstract:** An introduction to the principles of X-ray diffraction and crystal structure determination as it relates to Chemistry

**Prerequisites / notice:**

**Taught competencies:**
- Domain A - Subject-specific Competencies: Concepts and Theories

**Lecture notes:**
- The script and exercises will be distributed weekly in loose form
Literature

Main reference


Additional literature

(2) J.D. Dunitz, "X-ray Analysis and the Structure of Organic Molecules", 1995, Verlag HCA.


Computational Chemistry

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0002-00L</td>
<td>Algorithms and Programming in C++</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>S. Riniker, G. Landrum</td>
</tr>
</tbody>
</table>

Abstract

Introduction to algorithms (special focus on chemistry):
- Design of algorithms, data structures, search and sort algorithms, graphs, numerical algorithms, algorithms in cheminformatics, machine learning and bioinformatics
- Computer language: C++

Objective

Development of programming skills and craftsmanship in order to be able to deal with the complexity of computer applications in chemistry.

Content

- Introduction to algorithms (special focus on chemistry):
  - Design of algorithms, data structures, search and sort algorithms, graphs, numerical algorithms, algorithms in cheminformatics, machine learning and cheminformatics
  - Computer language: C++

Lecture notes

Script (in English) will be available

Literature


C++ programming:

Prerequisites / notice

Since the exercises on the computer do convey and test essentially different skills as those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam.

Materials Science

Offered during Spring Semester.

Environmental Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0037-01L</td>
<td>Introduction to Environmental Chemistry and Ecotoxicology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Hollender, T. Hofstetter, C. S. McArdell</td>
</tr>
</tbody>
</table>

Abstract

Anthropogenic activities related to production, use and disposal of goods cause emission of chemicals to the environment. This lecture provides an introduction to the knowledge required for assessing the risk of chemicals to human and environmental health by covering partitioning, reactivity, and toxic effects of chemicals as well as selected aspects of contemporary chemical analyses.

Objective

Students will develop a basic understanding for fate and effects of chemicals in the environment and learn how to use simple quantitative tools for the assessment of chemical behaviour and toxic effects.

Content

- Part 1: Partitioning and reactivity
  - Physico-chemical description of partitioning behaviour of organic compounds
  - Partitioning in environmental media including soil/sediment, air, water
  - Chemical and biological transformations

- Part 2: Effects
  - Test systems for the assessment of ecotoxicological effects of chemicals
  - Bioavailability and bioaccumulation
  - Metabolisms of organic compounds
  - Molecular mechanisms of toxic action

- Part 3: Analyses
  - Analytical methods for quantification of substances in water, soil, and air
  - Sampling, sample preparation and quantification of organic compounds in environmental media

Lecture notes

Handouts/lecture slides will be made available electronically

Literature


Taught competencies

- Domain A - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Domain D - Personal Competencies: Critical Thinking

Stratospheric Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1233-00L</td>
<td>Stratospheric Chemistry</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>T. Peter, G. Chiado</td>
</tr>
</tbody>
</table>

Abstract

The lecture gives an overview on the manifold reactions which occur in the gas phase, in stratospheric aerosol droplets and in polar cloud particles. The focus is on the chemistry of stratospheric ozone and its influence through natural and anthropogenic effects, especially the ozone depletion caused by FCKW in mid-latitude and polar regions as well as the coupling with the greenhouse effect.
The students will understand the gas phase reactions in the stratosphere as well as reactions and processes in aerosol droplets and polar stratospheric clouds. The students will understand the most important aspects of stratospheric dynamics and the greenhouse gas effect in troposphere and stratosphere. Furthermore, they will acquire a good understanding of the coupling between stratospheric ozone and climate change.

Short presentation of thermodynamical and kinetic basics of chemical reactions: bi- and termolecular reactions, photo-dissociation. Introduction to the chemical family concept: active species, their source gases and reservoir gases. Detailed treatment of the pure oxygen family (odd oxygen) according to the Chapman chemistry. Radical reactions of the oxygen species with nitric oxide, active halogens (chlorine and bromine) and odd hydrogen. Ozone depletion cycles. Methane depletion and ozone production in the lower stratosphere (photo-smog reactions). Heterogeneous chemistry on the background aerosol and its significance for heavy air traffic. Chemistry and dynamics of the ozone hole: Formation of polar stratospheric clouds and chlorine activation.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Documents are provided in the contact hours. 

Prerequisites / notice
Prerequisites: Basics in physical chemistry are required and an overview equivalent to the bachelor course in atmospheric chemistry (lecture 701-0471-01) is expected.

701-1233-00 V starts in the first week of the semester. The exercises 701-1233-00 U will start only in the 2nd week of the semester.

### Economics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

#### Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

#### Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

The course will consist of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The course will be assessed via a multiple choice exam.

### Critical Thinking

- Self-presentation and Social Influence
- Problem-solving
- Communication
- Critical Thinking

### Analytical Competencies

- Analytical Competencies
- Conceptual Competencies
- Conceptual and Theoretical

### Conceptual Competencies

- Conceptual Competencies
- Conceptual and Theoretical
- Conceptual and Theoretical

### Domain A - Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies

### Domain B - Method-specific Competencies

- Analytical Competencies
- Problem-solving

### Domain C - Social Competencies

- Communication
- Self-presentation and Social Influence

### Domain D - Personal Competencies

- Creative Thinking
- Critical Thinking

### GESS Science in Perspective

#### Science in Perspective

*see GESS Science in Perspective: Type A: Enhancement of Reflection Capability*

**Recommended GESS Science in Perspective (Type B) for D-CHAT.**

#### Language Courses

*see GESS Science in Perspective: Language Courses ETH/UBZH*
### Chemistry Bachelor - Key for Type

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

### Key for Hours

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

**ECTS** European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Cognitively Activating Instructions in MINT Subjects

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".

Objective
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives
- To integrate this knowledge with teachers' work

Abstract
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.

Research Methods in Educational Science

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

Literature from the learning sciences is critically discussed with a focus on research methods.

Prerequisites / notice
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

Gender Issues in Education and STEM

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

Objective
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives
- To integrate this knowledge with teachers' work

Abstract
In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.

Gender Issues in Education and STEM

In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.

Important Notice: Enrolment in the courses of this category is only possible if no more than 12 CP of potential additional requirements have to be acquired.

Mentored Work Subject Didactics Chemistry A

Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).
implementing findings from research into teaching and learning for chemistry lessons and coverage of subject-specific teaching and learning.

A. Baertsch
R. Ciorciaro

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Objective**

The objective is for the students:

- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

**Content**

Thematic Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen

Lecture notes
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Literature
The students have basic subject didactic knowledge for teaching chemistry at a secondary school.

Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>529-0960-00L</td>
<td>Mentored Work Subject Didactics Chemistry B</td>
<td>O</td>
<td>2</td>
<td></td>
<td>R. Ciorciaro</td>
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<tr>
<td>529-0966-00L</td>
<td>Introductory Internship Chemistry</td>
<td>O</td>
<td>3</td>
<td></td>
<td>A. Baertsch</td>
</tr>
</tbody>
</table>

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**Professional Training in Chemistry**

*Important Notice: Enrollment in the courses of this category is only possible if no more than 12 CP of potential additional requirements have to be acquired.*

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Simultaneous enrolment in Subject Didactics Chemistry I
- course 529-0950-00L - is compulsory.

Abstract
During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

Objective

Content

Literature
Wird von der Praktikumslehrperson bestimmt.

Prerequisites / notice
Das Einführungspraktikum findet an einem Gymnasium der Deutschschweiz statt.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Practice Period</th>
<th>Author</th>
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<tbody>
<tr>
<td>529-0964-00L</td>
<td>Teaching Internship Chemistry</td>
<td>8</td>
<td>4V</td>
<td>A. Baertsch</td>
</tr>
<tr>
<td>529-0955-00L</td>
<td>Professional Exercises: Experiments in Teaching Chemistry</td>
<td>2</td>
<td>4V</td>
<td>A. Baertsch</td>
</tr>
<tr>
<td>529-0968-01L</td>
<td>Examination Lesson I Chemistry</td>
<td>1</td>
<td>2P</td>
<td>A. Baertsch</td>
</tr>
</tbody>
</table>

Objective
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content

Literature
Wird von der Praktikumslehrperson bestimmt.

Prerequisites / notice
Findet in der Regel am Schluss der Ausbildung, vor Ablegung der Prüfungslektionen statt.

Objective
- Demonstrate experiments safely and convincingly
- Explain observations in a level-appropriate manner
- Use experiments to support theory
- Know why experiments need to be tested before demonstration
- Know some standard experiments
- Develop own experiments

Content
Schwerpunkte bilden die folgenden Themen:
- Theoretische Einführung
- Merkmale für ein sicheres Experimentieren
- Die Studierenden erproben und demonstrieren bereitstehende Experimente
- Experimente mit einer Skizze festhalten
- Auf Basis der Literatur ein Experiment selbständig ausarbeiten, dokumentieren und vorführen
- Experimente in den Unterricht einbetten
- Aufgaben zur Auswertung entwerfen

Lecture notes
Die Unterlagen und die im Kurs erarbeiteten Experimente sind auf http://fdchemie.pbworks.com zugänglich

Literature
H. Brandl, Trickkiste Chemie, Aulis-Verlag Deubner (2010)

Prerequisites / notice

Blockveranstaltung mit Anwesenheitspflicht an einem Gymnasium in Zürich.

Objective
- Will mark the conclusion of the teacher training program in Chemistry.

Abstract
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective
On the basis of a specified topic, the candidate shows that they are in a position
- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle
- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Lecture notes**

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.https://www.ethz.ch/content/dam/ethz/main/education/didaktische-ausbildung/files/diverses/schriktliche%20unterrichtsvorb%20%3bc%3b%3bc%3b%3bc%3b%3bc%3b%3b%C3%BC4fekt_04.11.2014..pdf

**Prerequisites / notice**

Nach Abschluss der übrigen Ausbildung.

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0962-00L</td>
<td>Fundamental Aspects of Chemistry with an Educational Focus B</td>
<td>O</td>
<td>4</td>
<td>2V</td>
<td>A. Togni, R. Alberto</td>
</tr>
<tr>
<td>529-0962-00L</td>
<td>Mentored Work with an Educational Focus Chemistry B for Teaching Diploma.</td>
<td>O</td>
<td>4</td>
<td>2V</td>
<td>A. Togni, R. Alberto</td>
</tr>
<tr>
<td>529-0968-01L</td>
<td>Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Chemistry B</td>
<td>O</td>
<td>4</td>
<td>2V</td>
<td>R. Ciocciaro</td>
</tr>
</tbody>
</table>

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**Content**

Will mark the conclusion of the teacher training program in Chemistry.

**Abstract**

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**

- On the basis of a specified topic, the candidate shows that they are in a position to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle.
- To analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**


**Lecture notes**

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.https://www.ethz.ch/content/dam/ethz/main/education/didaktische-ausbildung/files/diverses/schriktliche%20unterrichtsvorb%20%3bc%3b%3bc%3b%3bc%3b%3bc%3b%3b%C3%BC4fekt_04.11.2014..pdf

**Prerequisites / notice**

Nach Abschluss der übrigen Ausbildung.

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**Objective**

- In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.
- To analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.
- To develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle.
- To familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- To independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readers.
- To try out different options for specialist further training in their profession.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

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**Notice**

Prerequisites / notice

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**Notice**

Prerequisites / notice

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Prerequisites / notice

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**Notice**

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Prerequisites / notice

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Prerequisites / notice

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Prerequisites / notice

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Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.

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**Notice**

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.
Thematische Schwerpunkte:

Lernformen:

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

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

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

Compulsory Elective Courses

see Compulsory Elective Courses Teaching Diploma

Chemistry Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>Compulsory</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctorate</th>
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<tr>
<td>W+</td>
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Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Organic Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0233-01L</td>
<td>Organic Synthesis: Methods and Strategies</td>
<td>W+</td>
<td>6</td>
<td>3G</td>
<td>E. M. Carreira</td>
</tr>
</tbody>
</table>

**Abstract**: The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

**Objective**: Extension and deepening of the knowledge in organic synthesis and the principles of structure and reactivity.

**Content**: Concepts of the planning of organic synthesis (strategy and tactics), retrosynthetic analysis. Structure-reactivity relation in the context of the synthesis of complex molecules.


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### Organic Synthesis: Methods and Strategies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0241-10L</td>
<td>Advanced Methods and Strategies in Synthesis</td>
<td>W+</td>
<td>6</td>
<td>3G</td>
<td>J. W. Bode</td>
</tr>
</tbody>
</table>

**Abstract**: Introduction to modern methods in asymmetric stereocatalysis, enantioselective catalysis, and organic reaction mechanisms.

**Objective**: Current trends in methods for and approaches to synthesis of complex natural products, pharmaceuticals, and biological molecules; fragment coupling and protecting group strategies; chemical ligation and biomolecules synthesis; enantioselective catalysis including ligand design optimization; cross coupling reactions from preactivated precursors; C–H activation and oxidation chemistry; building block synthesis with chiral auxiliaries and reagents; new concepts in asymmetric catalysis. Analysis of key primary literature including identification of trends, key precendents, and emerging topics will be emphasized.

**Content**: Knowledge of modern methods in asymmetric stereocatalysis, enantioselective catalysis, and organic reaction mechanisms. Introduction to modern methods in asymmetric stereocatalysis, enantioselective catalysis, and organic reaction mechanisms.

**Literature**:

### Physical Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0433-01L</td>
<td>Advanced Physical Chemistry: Statistical Thermodynamics</td>
<td>W+</td>
<td>6</td>
<td>3G</td>
<td>R. Riek, J. Richardson</td>
</tr>
</tbody>
</table>

**Abstract**: Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.

**Objective**: Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.


**Literature**: See homepage of the course.

**Prerequisites / notice**: Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus)

**Taught competencies**:

- **Domain A - Subject-specific Competencies**: Concepts and Theories, assessed
- **Domain B - Method-specific Competencies**: Analytical Competencies, assessed
- **Domain C - Social Competencies**: Communication, assessed
- **Domain D - Personal Competencies**: Critical Thinking, assessed

---

### Research Projects

Students are accustomed to scientific work and they get to know one specific research field. During this semester course, methodologies will be taught for biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The relevant technologies will be taught to the students, such as the preparation of competent cells, production and isolation of DNA fragments, transformation of gene libraries, and DNA sequencing. The course participants will generate a variety of different variants of a chorismate mutase. Individual enzyme catalysts will be purified and subsequently characterized using several different spectroscope methods. The detailed chemical-physical analyses include determination of the enzymes' kinetic parameters, their molecular mass, and the integrity of the protein structure. The students will present the results obtained from their individual evolution experiments at the end of the semester. We expect that during this lab course we will not only generate novel enzymes, but also gain new mechanistic insights into the investigated catalyst.

### Industry Internship or Laboratory Course

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0200-10L</td>
<td>Research Project I</td>
<td>W</td>
<td>13 credits</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
<td></td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
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<tr>
<td>529-0201-10L</td>
<td>Research Project II</td>
<td>W</td>
<td>13 credits</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Students are accustomed to scientific work and they get to know one specific research field.</td>
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#### Industry Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0202-00L</td>
<td>Industry Internship</td>
<td>W</td>
<td>13 credits</td>
<td></td>
<td>Supervisors</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Internship in industry with a minimum duration of 7 weeks</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The aim of the internship is to make students acquainted with industrial work environments. During this time, they will have the opportunity to get involved in current projects of the host institution.</td>
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#### Biological Chemistry A: Technologies for Directed Evolution of Enzymes

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0739-10L</td>
<td>Advanced laboratory course or internship depending on lab course Biological Chemistry B</td>
<td>W</td>
<td>13 credits</td>
<td>16P</td>
<td>P. A. Kast</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Candidates must inquire with P. Kast no later than September 1st whether course will take place (no self-enrollment)</td>
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<tr>
<td><strong>Objective</strong></td>
<td>During this semester course, methodologies will be taught for biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. All technologies used for the experiments will be explained to the students in practice with the goal that they will be able to independently apply them for the course project and in future research endeavors. After the course, an individual report about the results obtained has to be prepared.</td>
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<tr>
<td><strong>Content</strong></td>
<td>This class conducts and supports experiments for a specifically designed genuine research project. We will carry out biological-chemical enzyme evolution experiments using molecular genetic mutation technologies and in vivo selection in recombinant bacterial strains. The relevant technologies will be taught to the students, such as the preparation of competent cells, production and isolation of DNA fragments, transformation of gene libraries, and DNA sequencing. The course participants will generate a variety of different variants of a chorismate mutase. Individual enzyme catalysts will be purified and subsequently characterized using several different spectroscope methods. The detailed chemical-physical analyses include determination of the enzymes' kinetic parameters, their molecular mass, and the integrity of the protein structure. The students will present the results obtained from their individual evolution experiments at the end of the semester. We expect that during this lab course we will not only generate novel enzymes, but also gain new mechanistic insights into the investigated catalyst.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>The necessary documents and protocols will be distributed to the participants during the course.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>General literature to &quot;Directed Evolution&quot; and chorismate mutases, e.g.:</td>
<td></td>
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<tr>
<td>Further information to registration and work hours: <a href="http://www.kast.ethz.ch/teaching.html">www.kast.ethz.ch/teaching.html</a></td>
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</table>

#### Taught competencies

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

- **Domain B - Method-specific Competencies**
  - Analytical Competencies
  - Problem-solving

- **Domain C - Social Competencies**
  - Communication

- **Domain D - Personal Competencies**
  - Adaptability and Flexibility
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

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### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0500-10L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>25 credits</td>
<td>54D</td>
<td>Supervisors</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Only students who fulfill the following criteria are allowed to begin with their Master's thesis:</td>
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a. successful completion of the Bachelor's programme;
b. fulfilling of any additional requirements necessary to
gain admission to the Master's programme.

Duration of the Master's Thesis 20 weeks.

Electives

Students are free to choose from a range of D-CHAB chemistry courses appropriate to their level of study (please note admission requirements). In case of doubt, contact the student administration.

Inorganic Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Abstract

General bonding concepts
AIM and ELF as descriptors of electronic structures
GCMC model, carbene and carbene analogues, homo and heteronuclear unsaturated bonds
Electron precise cluster, electron deficient cluster, and special cluster
General concepts and definitions of inorganic polymers, polysilanes, polysiloxanes, polyphosphazenes

Objective

The course starts with an introduction into general concepts allowing to understand why main group element and transition metal compounds from the higher periods show different properties when compared to their lighter congeners. The Atom in Molecule (AIM) Theory and Electron Localization Function (ELF) will be introduced as means to interpret the electron density distribution in molecules. Carbene and carbene analogues will be discussed as building blocks for compounds with unsaturated bonds which in turn may serve as precursors to inorganic polymers. Electron counting rules allow to distinguish different type of clusters which can be divided into electron precise cluster, various electron deficient cluster (for example Wade-Mingos-Cluster), and special cluster.

Inorganic polymers will be be discussed and possible applications of these polymers will be highlighted. Recent literature will be provided and discussed jointly by the participants of the course (flipped classroom).

Lecture notes

A handout of the presented material will be distributed to the participants of the course. Articles from recent literature will be provided and discussed in the course.

Literature

Original literature is indicated in the course material.

Prerequisites / notice

Basis for the understanding of this lecture are the courses Allgemeine Chemie 1&2, and Anorganische Chemie 1: Übergangsmetallichemie.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

Organic Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0243-01L</td>
<td>Transition Metal Catalysis: From Mechanisms to Applications</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>B. Morandi</td>
</tr>
</tbody>
</table>

Abstract

Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint

Objective

Understanding and critical evaluation of current research in transition metal catalysis. Design of mechanistic experiments to elucidate reaction mechanisms. Synthetic relevance of transition metal catalysis. Students will also learn about writing an original research proposal during a workshop.

Content

Detailed discussion of selected modern transition metal catalyzed reactions from a synthetic and mechanistic viewpoint. Synthetic applications of these reactions. Introduction and application of tools for the elucidation of mechanisms. Selected examples of topics include: C-H activation, C-O activation, C-C activation, redox active ligands, main group redox catalysis, binuclear catalysis.

Lecture notes

Lecture slides will be provided online. A Handout summarizing important concepts in organometallic and physical organic chemistry will also be provided. Useful references and handouts will also be provided during the workshop.

Slides will be uploaded 1-2 days before each lecture on http://morandi.ethz.ch/education.html


Autumn Semester 2021

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Primary literature and review articles will be cited during the course.

The following textbooks can provide useful support for the course:


Prerequisites / notice

Special requirement: each participant will have to come up with an independent research proposal to be presented orally (or handed in in written form) at the end of the semester. A dedicated workshop will be organized in the middle of the semester to introduce the students to proposal writing and presentation.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0233-01L</td>
<td>Organic Synthesis: Methods and Strategies</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>E. M. Carreira</td>
</tr>
</tbody>
</table>

Abstract

The complex relation between structural analysis, methods leading to desired transformations, and insight into reaction mechanisms is exemplified. Relations between retrosynthetic analysis of target structures, synthetic methods and their combination in a synthetic strategy.

Objective

Extension and deepening of the knowledge in organic synthesis and the principles of structure and reactivity.

Content


Literature


OC I-IV

Prerequisites / notice

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies not assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed

Domain C - Social Competencies

Communication assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation assessed

Domain D - Personal Competencies

Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

529-0241-10L Advanced Methods and Strategies in Synthesis W 6 credits 3G J. W. Bode

Abstract

Advanced Modern Methods and Strategies in Synthesis

Objective

Knowledge of modern methods in asymmetric stereocontrol,enantioselective catalysis, and organic reaction mechanisms.

Content

Current trends in methods for and approaches to synthesis of complex natural products, pharmaceuticals, and biological molecules; fragment coupling and protecting group strategies; chemical ligation and biomolecules synthesis; enantioselective catalysis including ligand design and optimization; cross coupling reactions from preactivated precursors; C-H activation and oxidation chemistry; building block synthesis with chiral auxiliaries and reagents; new concepts in asymmetric catalysis. Analysis of key primarily literature including identification of trends, key precendents, and emerging topics will be emphasized.

Lecture notes

will be provided in class and online

Literature

Suggesting Textbooks


Physical Chemistry

Number

529-0433-01L Advanced Physical Chemistry: Statistical Thermodynamics W 6 credits 3G R. Riek, J. Richardson

Abstract

Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.

Objective

Introduction to statistical mechanics and thermodynamics. Prediction of thermodynamic and kinetic properties from molecular data.

Content


Lecture notes

See homepage of the lecture.

Literature

See homepage of the lecture.

Prerequisites / notice

Chemical Thermodynamics, Reaction Kinetics, Molecular Quantum Mechanics and Spectroscopy; Mathematical Foundations (Analysis, Combinatorial Relations, Integral and Differential Calculus)
Basic: Absorption and Scattering of Light by Small Particles, C. F. Bohren and D. R. Huffman, John Wiley & Sons, Inc.

Light interacts surprisingly differently with small particles than with bulk or gas phase materials. The first part of the course provides a problem-oriented development of analytical strategies and solutions.

The course starts with a recapitulation of density operator and product operator formalism with special emphasis on electron-nuclear spin systems in the solid state. We then treat basic phenomena, such as passage effects, Wavel crossings, and hyperfine decoupling. Based on these foundations, we discuss polarization transfer from the electron to the nuclear spin and back, as well as spin diffusion as a mechanism for polarizing nuclear spins beyond the immediate vicinity of the electron spin. The second half of the course will cover dynamic nuclear polarization (DNP), with a focus on instrumentation required to perform pulsed DNP with magic angle spinning (MAS) NMR, and electron decoupling with MAS will motivate discussions of technology development. Specific technologies to be covered include, but are not limited to, frequency agile gyrotron oscillators, corrugated waveguides, microwave lenses, strategies for creating pulsed and frequency chirped microwaves, spherical MAS rotors and supporting stators, high temperature superconductor (HTS) based compact magnets, and radio-frequency circuits for multinuclear spin control and detection.

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book "Spin Dynamics" by Malcolm Levitt.

Lecture notes
A script which covers the topics will be distributed in the lecture and will be accessible through the course Moodle

Advanced Optics and Spectroscopy
This course provides an introduction to the interaction of light with nano- and microparticles followed by an overview of applications of current interest. Examples range from nanoparticles for medical applications and sensing to the role of the interaction of solar radiation with aerosol particles and cloud droplets for the climate.

Objective
The students will be introduced to the basic concepts of the interaction of light with nano- and microparticles. The combination of basic concepts with different applications will enable students to apply their knowledge to new problems in various fields where nanoscale objects play a role.

Content
Light interacts surprisingly differently with small particles than with bulk or with gas phase materials. The first part of the course provides a basic but rigorous introduction into the interaction of light with nano- and microparticles. The emphasis is on the classical treatment of absorption and scattering of light by small particles. The strengths and limits of this conventional approach will be discussed. The second part of the course is devoted to a broad range of applications. Here topics include: Plasmon resonances in metallic systems, metallo-dielectric nanoparticles for medical applications, the use of lasers for optical trapping and characterization of single particles, vibrational excitons in dielectric nanoparticles, interaction of light with aerosol particles and cloud droplets for remote sensing applications and climate predictions, characterization of ultrafine aerosol particles by photoemission using velocity map imaging.

Lecture notes
will be distributed during the course

Advanced Magnetic Resonance
The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. This semester, the lecture will introduce and discuss the dynamics of electron-nuclear spin systems and experiments based on hyperfine interactions in electron paramagnetic resonance (EPR) spectroscopy and dynamic nuclear polarization (DNP) for sensitivity enhancement in NMR.

Objective
The course aims at enabling students to understand and design experiments that are based on hyperfine coupling between electron and nuclear spins. This includes analytical and numerical treatment of spin dynamics as well as instrumental aspects. Additionally, students will learn how to use hyperfine couplings to increase sensitivity in solid state NMR via dynamic nuclear polarization (DNP), with an emphasis on the instrumentation required to perform DNP with magic angle spinning (MAS) NMR.

Content
The course starts with a recapitulation of density operator and product operator formalism with special emphasis on electron-nuclear spin systems in the solid state. We then treat basic phenomena, such as passage effects, Wavel crossings, and hyperfine decoupling. Based on these foundations, we discuss polarization transfer from the electron to the nuclear spin and back, as well as spin diffusion as a mechanism for polarizing nuclear spins beyond the immediate vicinity of the electron spin. The second half of the course will cover dynamic nuclear polarization (DNP), with a focus on instrumentation required to perform pulsed DNP with magic angle spinning (MAS) NMR, and electron decoupling with MAS will motivate discussions of technology development. Specific technologies to be covered include, but are not limited to, frequency agile gyrotron oscillators, corrugated waveguides, microwave lenses, strategies for creating pulsed and frequency chirped microwaves, spherical MAS rotors and supporting stators, high temperature superconductor (HTS) based compact magnets, and radio-frequency circuits for multinuclear spin control and detection.

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book "Spin Dynamics" by Malcolm Levitt.

Lecture notes
A script which covers the topics will be distributed in the lecture and will be accessible through the course Moodle

Analytical Competencies
This course provides an introduction to the interaction of light with nano- and microparticles followed by an overview of applications of current interest. Examples range from nanoparticles for medical applications and sensing to the role of the interaction of solar radiation with aerosol particles and cloud droplets for the climate.

Objective
The students will be introduced to the basic concepts of the interaction of light with nano- and microparticles. The combination of basic concepts with different applications will enable students to apply their knowledge to new problems in various fields where nanoscale objects play a role.

Content
Light interacts surprisingly differently with small particles than with bulk or with gas phase materials. The first part of the course provides a basic but rigorous introduction into the interaction of light with nano- and microparticles. The emphasis is on the classical treatment of absorption and scattering of light by small particles. The strengths and limits of this conventional approach will be discussed. The second part of the course is devoted to a broad range of applications. Here topics include: Plasmon resonances in metallic systems, metallo-dielectric nanoparticles for medical applications, the use of lasers for optical trapping and characterization of single particles, vibrational excitons in dielectric nanoparticles, interaction of light with aerosol particles and cloud droplets for remote sensing applications and climate predictions, characterization of ultrafine aerosol particles by photoemission using velocity map imaging.

Lecture notes
will be distributed during the course

Analytical Methods for Characterization of Nanoparticles and Nanomaterials
Does not take place this semester.

Abstract
Introduction to modern analytical methods used to fully characterize and identify nano-engineered materials and systems. Understanding of analytical concepts used in nanotechnology. In-depth knowledge of most important methods used in industry and research. Introduction to selected industrial applications. Basic knowledge of production mechanisms of nano-engineered materials.

Content
Nanotechnology is the basis of many main technological innovations of the 21st century. After more than twenty years of research, nanotechnologies are now increasingly employed for commercial use: they are used in hundreds of everyday consumer products, such as cosmetics, food, automotive, electronics and medical products. Nanoparticles can contribute to stronger, lighter, cleaner, smarter, better, etc. products. Besides these positive effects, relatively little is still known about potential health and environmental effects and risks of such small nanosized particles. Therefore, a lot of different industry customers are forced nowadays to monitor and regulate the size and concentration of nanoparticles in their nano-enabled products.

Above and beyond these regulatory requirements, most industries employing nanoparticles need to be able to online measure nanoparticles to meet their requirements towards quality control and production efficiency. All these requirements demand new precise, accurate, fast and innovative analysis methods to fully characterize nanoparticles in real-time and during the manufacturing process.

Lecture notes
Lecture notes will be provided
### Biological Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0733-01L</td>
<td>Enzymes</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>D. Hilvert</td>
</tr>
</tbody>
</table>

**Abstract**

Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme-catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

**Objective**

Overview of enzymes, enzyme-catalyzed reactions and metabolic processes.

**Content**

Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme-catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

**Lecture notes**

A script will not be handed out.

**Literature**

General:


In addition, citations from the original literature relevant to the individual lectures will be assigned weekly.

### Chemical Aspects of Energy

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-0209-00L</td>
<td>Renewable Energy Technologies</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Steinfield, E. I. M. Casati</td>
</tr>
</tbody>
</table>

**Abstract**

Renewable energy technologies: solar PV, solar thermal, biomass, wind, geothermal, hydro, waste-to-energy. Focus is on the engineering aspects.

**Objective**

Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

**Lecture notes / Prerequisites**

Lecture Notes containing copies of the presented slides.

Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

### Chemical Crystallography

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0029-01L</td>
<td>Structure Determination</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. D. Wörle, N. Trapp</td>
</tr>
</tbody>
</table>

**Abstract**

Advanced X-ray crystal structure analysis

**Objective**

To gain a deeper understanding of crystal structure determination principles and practice by X-ray diffraction and the evaluation of results.

**Content**

Review of principles of diffraction and instrumentation, unit cells, lattices, and symmetry. Inorganic structural chemistry: sphere packings, ionic crystals, covalent networks, intermetallic compounds. Overview of powder diffraction and application of crystal chemistry for structure analysis of polycrystalline phases. Working safely with X-rays, crystal growth, selection and mounting, data collection strategies, data reduction, corrections for absorption, extinction and Lp, advanced structure solution theory and techniques: Patterson function, heavy atom technique, Fourier methods, direct methods. Structure modeling and refinement, disorder, twinning, false symmetry, interpretation of anisotropic shift parameters. Determination of absolute configuration, interpretation of results and scope of chemically useful information, validation and publication of results, critical evaluation of published crystal structures.

**Lecture notes / Literature**

Information and exercise sheets will be distributed in loose form.


(2) J.D. Dunitz, *"X-ray Analysis and the Structure of Organic Molecules"*, 1995, Verlag HCA.

Additional literature


(5) D. Blow, *"Outline of Crystallography for Biologists"*, 2002 Oxford University Press.


### Chemical Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>636-0108-00L</td>
<td>Biological Engineering and Biotechnology</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>M. Fussenegger</td>
</tr>
</tbody>
</table>

**Abstract**

Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.
Computational Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0003-01L</td>
<td>Advanced Quantum Chemistry</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Reiher, A. Baiardi</td>
</tr>
</tbody>
</table>

Abstract
Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer. Examples are:
* Operators derived from principles of relativistic quantum mechanics
* Relativistic effects - methods of relativistic quantum chemistry
* Open-shell molecules + spin-density functional theory
* New electron-correlation theories

Objective
The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. These insights are the Bopp-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.

Content
1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon and Dirac equation: the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group
9) Quantum chemistry without the Born-Oppenheimer approximation

Prerequisites / notice
Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry.

Lecture notes
Handout during the course.

Literature
A set of detailed lecture notes will be provided, which will cover the whole course.

Prerequisites / notice
Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry.

Abstract
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Objective
Introduction to classical (atomistic) computer simulation of (bio)moloecular systems, development of skills to carry out and interpret these simulations.

Content
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes
The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

Prerequisites / notice
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS
This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental explanation of important interactions between xenobiotic chemicals and cellular structures such as membranes, enzymes, and nucleic acids. Understanding of the impact of chemicals on biological systems; evaluation of the effects from different biomedical perspectives. This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change.

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

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.
The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2020), Economics, Cengage Learning, Fifth Edition. This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

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

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

363-0503-00L Principles of Microeconomics
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Abstract
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

Objective
The learning objectives of the course are:
1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

Content
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:
- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

Lecture notes
Lecture notes, exercises and reference material can be downloaded from Moodle.

Literature
The book can also be used for the course "Principles of Macroeconomics" (Sturm)

For students taking only the course "Principles of Microeconomics" there is a shorter version of the same book:

Complementary:

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
Inorganic Chemistry

529-0143-01L Aspects of Modern Inorganic Chemistry: Concepts, Building Blocks, and Polymers

W+ 6 credits 3G H. Grützmacher, J. Grützmacher

Abstract

General bonding concepts
AIM and ELF as descriptors of electronic structures
GCMT model, carbenes and carbene analogues, homo and heteronuclear unsaturated bonds
Electron precise cluster, electron deficient cluster, and special cluster

Objective

The course starts with an introduction into general concepts allowing to understand why main group element and transition metal compounds from the higher periods show different properties when compared to their lighter congeners. The Atom in Molecule (AIM) Theory and Electron Localization Function (ELF) will be introduced as means to interpret the electron density distribution in molecules.

The course will discuss carbenes and carbene analogues as building blocks for compounds with unsaturated bonds which in turn may serve as precursors to inorganic polymers.

Electron counting rules allow to distinguish different type of clusters which can be divided into electron precise cluster, various electron deficient cluster (for example Wade-Mingos-Cluster), and special cluster.

An introduction into general concepts for syntheses and analyses of inorganic polymers will be given. Specifically, polysilanes, polysiloxanes, and polyphosphazenes will be discussed and possible applications of these polymers will be highlighted.

Recent literature will be provided and discussed jointly by the participants of the course (flipped classroom).

The main goal of the lecture is to provide a general understanding of the current literature in the field of modern inorganic chemistry with respect to building blocks used for the synthesis of cluster, polymers, and materials.

Lecture notes

A handout of the presented material will be distributed to the participants of the course. Articles from recent literature will be provided and discussed in the course.

Literature

Original literature is indicated in the course material.

Prerequisites / notice

Basis for the understanding of this lecture are the courses Allgemeine Chemie 1&2, and Anorganische Chemie 1: Übergangsmetallichemie.

Physical Chemistry

529-0443-01L Advanced Magnetic Resonance

W+ 6 credits 3G G. Jeschke, A. Barnes
Abstract
The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. This semester, the lecture will introduce and discuss the dynamics of electron-nuclear spin systems and experiments based on hyperfine interactions in electron paramagnetic resonance (EPR) spectroscopy and dynamic nuclear polarization (DNP) for sensitivity enhancement in NMR.

Objective
The course aims at enabling students to understand and design experiments that are based on hyperfine coupling between electron and nuclear spins. This includes analytical and numerical treatment of spin dynamics as well as instrumental aspects. Additionally, students will learn how to use hyperfine couplings to increase sensitivity in solid state NMR via dynamic nuclear polarization (DNP), with an emphasis on the instrumentation required to perform DNP with magic angle spinning (MAS) NMR.

Content
The course starts with a recapitulation of density operator and product operator formalism with special emphasis on electron-nuclear spin systems in the solid state. We then treat basic phenomena, such as passage effects, avoided level crossings, and hyperfine decoupling. Based on these foundations, we discuss polarization transfer from the electron to the nuclear spin and back, as well as spin diffusion as a mechanism for polarizing nuclear spins beyond the immediate vicinity of the electron spin. The second half of the course will cover dynamic nuclear polarization (DNP), with a focus on instrumentation required to perform pulsed DNP with magic angle spinning (MAS) at ultra-high magnetic fields. A review of salient interactions in the NMR solid state NMR Hamiltonian, DNP mechanisms, and electron decoupling with MAS will motivate discussions of technology development. Specific technologies to be covered include, but are not limited to, frequency agile gyromotion oscillators, corrugated waveguides, microwave lenses, strategies for creating pulsed and frequency chirped microwaves, spherical MAS rotors and supporting stators, high temperature superconductor (HTS) based compact magnets, and radio-frequency circuits for multinuclear spin control and detection.

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book "Spin Dynamics" by Malcolm Levitt.

Lecture notes
A script which covers the topics will be distributed in the lecture and will be accessible through the course Moodle.

529-0445-01L Advanced Optics and Spectroscopy
W 6 credits 3G R. Signorell, G. David

Abstract
This course provides an introduction to the interaction of light with nano- and microparticles followed by an overview of applications of current interest. Examples range from nanoparticles for medical applications and sensing to the role of the interaction of solar radiation with aerosol particles and cloud droplets for the climate.

Objective
The students will be introduced to the basic concepts of the interaction of light with nano- and microparticles. The combination of basic concepts with different applications will enable students to apply their knowledge to new problems in various fields where nanoscale objects play a role.

Content
Light interacts surprisingly differently with small particles than with bulk or with gas phase materials. The first part of the course provides a basic but rigorous introduction into the interaction of light with nano- and microparticles. The emphasis is on the classical treatment of absorption and scattering of light by small particles. The strengths and limits of this conventional approach will be discussed. The second part of the course is devoted to a broad range of applications. Here topics include: Plasmon resonances in metallic systems, metallo-dielectric nanoparticles for medical applications, the use of lasers for optical trapping and characterization of single particles, vibrational excitons in dielectric nanoparticles, interaction of light with aerosol particles and cloud droplets for remote sensing applications and climate predictions, characterization of ultrafine aerosol particles by photoemission using velocity map imaging.

Lecture notes
will be distributed during the course

Literature
Basics: Absorption and Scattering of Light by Small Particles, C. F. Bohren and D. R. Huffman, John Wiley & Sons, Inc.

Fundamental aspects of the organometallic chemistry of the transition elements. Mechanistic homogeneous catalysis including oxidative

targets of quantum mechanics, operator algebra, Schrödinger's equation, state functions and expectation values, matrix representation

elements. Mechanistic homogeneous catalysis including oxidative

enhanced knowledge about the elemental analysis and spectroscopical techniques with close relation to practical applications. This course

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

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Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
Introduction to magnetic resonance in isotropic and anisotropic phase.


529-0432-AAL

Physical Chemistry IV: Magnetic Resonance

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

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

Abstract

Theoretical foundations of magnetic resonance (NMR, EPR) and selected applications.

Objective

Introduction to magnetic resonance in isotropic and anisotropic phase.

Content

The course gives an introduction to magnetic resonance spectroscopy (NMR and EPR) in liquid, liquid crystalline and solid phase. It starts from a classical description in the framework of the Bloch equations. The implications of chemical exchange are studied and two-dimensional exchange spectroscopy is introduced. An introduction to Fourier spectroscopy in one and two dimensions is given and simple 'pulse trickery' is described. A quantum-mechanical description of magnetic resonance experiments is introduced and the spin Hamiltonian is derived. The chemical shift term as well as the scalar, dipolar and quadrupolar terms are discussed. The product-operator formalism is introduced and various experiments are described, e.g. polarization transfer. Applications in chemistry, biology, physics and medicine, e.g. determination of 3D molecular structure of dissolved molecules, determination of the structure of paramagnetic compounds and imaging (MRI) are presented.

Lecture notes

handed out in the lecture (in English)

see http://www.ssnmr.ethz.ch/education/PC_IV_Lecture

Literature

none

529-0129-AAL

Inorganic and Organic Chemistry II

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

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

This course does not offer a lecture of its own but it is linked to the course 529-0129-00L.

Abstract

Introduction to the experimental methods of Inorganic Chemistry

Objective

The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc.. The synthesis, characterization and analysis of inorganic compounds are a main topic. Emphasis is given to scientific writing (experiment reports).

Content

Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds.

Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

A manual is distributed in the teaching laboratory.

Prerequisites / notice

Prerequisites:
- Practical Course General Chemistry (1. Semester, 529-0011-04)
- Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230)
- Attendance of Course Inorg. Chemistry 1 (3. Sem., 529-0121)

If necessary, access priority will be settled according to the results of the first-year examinations.

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

551-0103-AAL

Fundamentals of Biology II: Cell Biology

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

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

Abstract

The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective

The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Content

The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Literature


Topic/Lecturer/Chapter/Pages:

- Analyzing cells & molecules / Gebhard Schertler/8 439-463;
- Membrane structure / Gebhard Schertler/ 10/ 565-595;
- Compartments and Sorting/ Ulrike Kutay/12+14+6/641-694/755-758/782-783/315-320/325 -333/Table 6-2/Figure6-20, 6-21, 6-32, 6-34;
- Intracellular Membrane Traffic/ Ulrike Kutay/13/695-752;
- The Cytoskeleton/ Ulrike Kutay/16/989 - 948 (only the essentials);
- Membrane Transport of Small Molecules and the Electrical Properties of Membranes /Sabine Werner/11/597 - 633;
- Mechanisms of Cell Communication / Sabine Werner/15/813-876;
- Cancer/ Sabine Werner/20/1091-1141;
- Cell Junctions and Extracellular Matrix/Ueli Suter / 1035-1081;
- Stem Cells and Tissue Renewal/Ueli Suter /1217-1262;
- Development of Multicellular organisms/ Ernst Hafeni/ 21/ 1145-1179/1184-1198/1198-1213;
- Cell Migration/Joao Matos/951-960;
- Cell Death/Joao Matos/1021-1032;
- Cell Cycle/chromosome segregation/Cell division/Mitosis/Joao Matos/ 963-1018.

Prerequisites / notice

none
### Chemistry Master - Key for Type

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

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

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Chemical and Bioengineering Master

Core Subjects

Biochemical and Polymer Reaction Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0837-01L</td>
<td>Biomicrofluidic Engineering</td>
<td>W+</td>
<td>6</td>
<td>3G</td>
<td>A. de Mello</td>
</tr>
</tbody>
</table>

**Abstract**

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-μL environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

**Objective**

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

**Content**

Specific topics covered in the course include, but are not limited to:

1. **Theoretical Concepts**
   - Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. **Microfluidic Device Manufacture**
   - Basic principles of conventional lithography of rigid materials, ‘soft’ lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. **Electrokinetics**
   - Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. **Mass Transfer Phenomena**
   - Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. **Heat Transfer Phenomena**
   - Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. **Microfluidic Systems for Materials Synthesis**
   - Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. **Point-of-Care Diagnostics**
   - Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. **Microscale DNA Amplification**
   - Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. **Small Volume Molecular Detection**
   - Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. **Droplets and Segmented Flows**
    - Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. **Single Cell Analysis**
    - Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

**Lecture notes**

Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

**Literature**

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>Project Management</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>Cooperation and Teamwork</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptable and Flexibility</td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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</table>

529-0837-01L

**Abstract**


**Objective**

The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.
Content

We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes. Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.

Lecture notes

Scripts are available on the web page of the Arosio-group: http://www.arosiogroup.ethz.ch/education.html

Additional handout of slides will be provided during the lectures.

Literature

H.W. Blanch, D. S. Clark, Biochemical Engineering, CRC Press, 1995

Products and Materials

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0619-01L</td>
<td>Chemical Product Design</td>
<td>W+</td>
<td>6 credits</td>
<td>3G</td>
<td>W. J. Stark</td>
</tr>
</tbody>
</table>

Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).

Abstract

The 'Chemical Product Design' course teaches students quantitative concepts to analyze, select and transform theoretical concepts from chemistry and engineering into valuable real-world products. Basic chemistry and chemical engineering knowledge is required (Diffusion, Thermodynamics, Kinetics, ...).

Objective

This course starts with analyzing existing chemical needs and unmet technical challenges. We then develop the skills to critically analyze a specific chemical idea for a product, to rapidly test feasibility or chance for success and to eventually realize its manufacturing. The chemical engineering basics are then used to assess performance of products or devices with non-traditional functions based on dynamic properties (e.g. responsive building materials, personal medical diagnostics on paper strips). The course teaches the interface between laboratory and market with a specific focus on evaluating the chemical value of a given product or compound, and the necessary steps to pursue the resulting project within an entrepreneurial environment. We therefore extend the questions of process design ("how do we make something?") to the question of "what should we make?"

Content

Part A: The 'Chemical Product Design' course starts with discussing questions along, 'What is a chemical product, and why do people pay for it? How does a given compound in a specific setting provide a service?' We then learn how to translate new, often ill-defined wishes or ideas into quantifiable specifications.

Part B: Thermodynamic and kinetic data allow sharp selection criteria for successful products. We learn how to deal with insufficient data and development of robust case models to evaluate their technical and financial constraints. How can parameters of a running process in one industry be scaled into another industry? Can dimensionless engineering numbers be applied beyond traditional chemical processes?

Part C: Manufacturing of commodity products, devices and molecular products: Chemical reactors, separation and detection or isolation units as part of a toolbox. Planning of manufacturing and decisions based on hard data. Providing quantitative answers on potential value generated.

Students are expected to actively develop chemical products along the course. Contributions will be made individually, or in small groups, where a larger topic is studied.

Literature


Prerequisites / notice

Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics,...).

Process Design

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0643-01L</td>
<td>Process Design and Development</td>
<td>W+</td>
<td>6 credits</td>
<td>3G</td>
<td>G. Guillén Gosálbez</td>
</tr>
</tbody>
</table>

Abstract

The course is focused on the design of Chemical Processes, with emphasis on the preliminary stages of the design approach, where process creation and quick selection among many alternatives are important. The main concepts behind more detailed process design and process simulation are also examined.

Objective


Lecture notes

no script
Overview of process simulation and flowsheeting:
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.

Prerequisites / notice
Prequisite: Basic knowledge on unit operations, mainly reaction engineering and distillation. It is recommended that the student takes the module "Process Simulation and Flowsheeting" before "Process Design and Development", but it is not mandatory.

Literature

Other references

Process Simulation and Flowsheeting

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>W+</td>
<td>6</td>
<td>3V+1U</td>
<td>M. Mazzotti, V. Becattini</td>
</tr>
</tbody>
</table>

Abstract
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.

Objective
The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.
Content

The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

Lecture notes

Handouts during the class

Literature

Recommendations for text books will be covered in the class

Prerequisites / notice

Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies

- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies

- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

529-0617-01L Catalysis Engineering W+ 6 credits 3G J. Pérez-Ramírez, S. J. Mitchell

Abstract

The purpose of the "Catalysis Engineering" course is to provide students with tools that enable the optimal design of catalytic materials and reactor engineering concepts favoring more sustainable manufacturing processes within the chemical industry.

Objective

The course aims at illustrating, from conception to implementation, the design of sustainable catalytic processes by integration of the microlevel (catalyst), mesolevel (reactor), and macrolevel (process). The word "sustainable" implies intensified processes with an improved exploitation of raw materials, wider use of renewable feedstocks, reduction of energy consumption, and minimized environmental impact. By the use of modern case studies of industrial relevance, aspects of catalyst preparation and characterization, kinetics, mass and heat transport, and deactivation are discussed. Emphasis is put on understanding the interaction among these basic elements in order to select the optimal catalytic process. Since no textbooks covering this area are available at this time and the intention of this course is unique, the lectures will be based on own texts and journal articles. During the course, there will be specific topics addressed by industrial contributors.

Content

The following general aspects:

- Catalyst preparation and characterization
- Kinetics
- Mass and heat transport
- Selectivity
- Deactivation

will be demonstrated for modern catalytic materials and processes of industrial relevance such as:

- Chlorine recycling
- N2O abatement
- Chemoselective hydrogenations
- Hierarchical zeolite catalysts
- Syngas conversion
- Biomass to chemicals and fuels

Lecture notes

The course material is based on an own script, journal articles, and slides.

Prerequisites / notice

It is assumed that students selecting this course are familiar with general concepts of catalysis, reactor design, and transport phenomena.

Case Study

Number Title Type ECTS Hours Lecturers


Abstract

The learning objective is to design, simulate and optimize a real (bio-)chemical process from a process systems perspective. Specifically, a commercial process simulation software (Aspen) will be used for the process simulation and optimization. Students have to integrate knowledge and develop engineering thinking and skills acquired in the other courses of the curriculum.

Objective

Simulate and optimize a chemical production process using commercial process simulation software.
Create a model describing the production process
- Students will apply a commercial process simulator systematically for process creation and analysis.
- Students will create a process simulation flowsheet for steady-state simulation.

Evaluate the performance of the production process
- Students will analyse and understand the degrees of freedom in modelling process units and flowsheets.
- Students will understand the role of process simulators in process creation.
- Students will make design specifications and follow the iterations implemented to satisfy them.
- Students will judge the role of process simulators in equipment sizing and costing and profitability analysis.
- Students will assess the economic performance of the process, including operating costs (OPEX), and capital investment (CAPEX), based on the outcome of the simulation model.
- Students will assess the environmental impact of the production process following the Life Cycle Assessment (LCA) methodology.

Optimize the design and operating conditions of the production process
- Students will carry out sensitivity analyses and optimizations considering technical and economic criteria.
- Students will generate process integration alternatives to improve the initial design.
- Students will optimize the production process considering economic and environmental criteria.

Before the case study week, students are encouraged to participate in the exercises of the course "Process Simulation and Flowsheeting" in order to familiar with the Aspen Plus simulation software (this is highly recommended, but not mandatory).

The problem statement and detailed instructions are provided in the project brief made available at the beginning of the case study week.

During the case study week:
- Students work in teams of 4-6 people.
- Students have to pose and solve process equipment and system design related problems.
- Students have to coordinate the activities, the preparation of the written report and the oral presentation.
- Students get support from project assistants and the course supervisor.

The groups deliver the written report on a predefined date.

The students receive the feedback and are asked to implement some changes in their reports.

A final presentation takes place summarizing the main findings of the project.

**Research Project or Industry Internship**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>529-0300-10L</td>
<td>Research Project</td>
<td>W</td>
<td>13 credits</td>
<td>16A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
<td>In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.</td>
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<tr>
<td>Objective</td>
<td>First contact with experimental techniques of chemical engineering in a research group. Critical evaluation and presentation of the results in a scientific report.</td>
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<tr>
<td>Content</td>
<td>This laboratory project is organised during the spring vacation before the sixth semester. The participant can choose his topic from the list of projects suggested. Main emphasis during this research work is to get experience in using different engineering tools and evaluation and the interpretation of the results. Those are presented as a scientific report.</td>
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<tbody>
<tr>
<td>529-0301-00L</td>
<td>Industry Internship</td>
<td>W</td>
<td>13 credits</td>
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<td>Supervisors</td>
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<tr>
<td>Abstract</td>
<td>Internship in industry with a minimum duration of 7 weeks</td>
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<tr>
<td>Objective</td>
<td>The aim of the internship is to make students acquainted with industrial work environments. During this time, they will have the opportunity to get involved in current projects of the host institution.</td>
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**Master's Thesis**

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<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0600-10L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>25 credits</td>
<td>54D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>
| Only students who fulfill the following criteria are allowed to begin with their Master's thesis:  
a. successful completion of the Bachelor's programme;  
b. fulfilling of any additional requirements necessary to gain admission to the Master's programme. |

Duration of the Master's Thesis 20 weeks.

**Electives**

**Biochemical Engineering**

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<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>636-0108-00L</td>
<td>Biological Engineering and Biotechnology</td>
<td>W</td>
<td>4 credits</td>
<td>3V</td>
<td>M. Fussenegger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.</td>
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</table>
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Handouts and references therin.


Introduction into molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Handouts are deposited online (moodle).

Handouts and references therin.


The aim of the course is to learn how to design polymerization reactors and bioreactors to produce polymers and proteins with the specific product qualities that are required by different applications in chemical, pharmaceutical and food industry. This activity includes the post-treatment of polymer latexes, the downstream processing of proteins and the analysis of their colloidal behavior.

We will cover the fundamental processes and the operation units involved in the production of polymeric materials and proteins. In particular, the following topics are discussed: Overview on the different polymerization processes, Kinetics of free-radical polymerization and use of population balance models. Production of polymers with controlled characteristics in terms of molecular weight distribution. Kinetics and control of emulsion polymerization. Surfactants and colloidal stability. Aggregation kinetics and aggregate structure in conditions of diffusion and reaction limited aggregation. Modeling and design of colloid aggregation processes. Physico-chemical characterization of proteins and description of enzymatic reactions. Operation units in bioprocessing: upstream, reactor design and downstream. Industrial production of therapeutic proteins. Characterization and engineering of protein aggregation. Protein aggregation in biology and in biotechnology as functional materials.

Scripts are available on the web page of the Arosio-group: http://www.arosigroup.ethz.ch/education.html

Additional handout of slides will be provided during the lectures.

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-ul environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.
We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.

2. Microfluidic Device Manufacture
   Basic principles of conventional lithography of rigid materials, ‘soft’ lithography, polymer machining (injection molding, hot embossing, and 3D-printing).

3. Electrokinetics
   Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.

4. Mass Transfer Phenomena
   Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damköhler numbers.

5. Heat Transfer Phenomena
   Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.

6. Microfluidic Systems for Materials Synthesis
   Microfluidic reactors for the controlled synthesis of colloidial nanomaterials, advanced automation for bespoke materials discovery & characterization.

7. Point-of-Care Diagnostics
   Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.

8. Microscale DNA Amplification
   Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.

9. Small volume Molecular Detection
   Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.

10. Droplets and Segmented Flows
    Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.

11. Single Cell Analysis
    Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.

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<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Steinfeld, E. I. M. Casati</td>
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<td>Analytical Competencies</td>
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**Environment and Energy**

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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0209-00L</td>
<td>Renewable Energy Technologies</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>A. Steinfeld, E. I. M. Casati</td>
</tr>
<tr>
<td></td>
<td>Renewable energy technologies: solar PV, solar thermal, biomass, wind, geothermal, hydro, waste-to-energy. Focus is on the engineering aspects.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture Notes containing copies of the presented slides.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.</td>
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<tr>
<td>529-0659-00L</td>
<td>Electrochemistry: Fundamentals, Cells &amp; Applications</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>L. Gubler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to electrochemistry from a physical chemistry point of view, focusing on thermodynamics and kinetics of electrochemical reactions, and engineering of electrochemical cells. The topics are of generic nature yet also discussed in the context of specific applications in industrial electrochemistry, energy storage and conversion, electroanalytical techniques, sensors and corrosion.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The course establishes the fundamentals to understand and describe electrochemical reactions. The students are familiarized with key concepts and approaches in electrochemistry and selected aspects of materials science and engineering and how they are put to use in selected applications.</td>
<td></td>
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</tr>
</tbody>
</table>
Concepts and Theories

Type

J. A. van Bokhoven

ECTS

Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent

Basic aspects of surface science. Understanding of principles of most important experimental methods used in research concerned with

Lecturers

assessed

- Properties of laminar, transitional and turbulent flows.
- Turbulent flow computation and modeling.
- Origin and control of turbulence. Instability and transition.
- Statistical description, averaging, equations for mean and fluctuating quantities, closure problem.
- Scalings, homogeneous isotropic turbulence, energy spectrum.
- Turbulent free shear flows. Jet, wake, mixing layer.
- Wall-bounded turbulent flows.
- Turbulent flow computation and modeling.
- Introduction: important quantities & units, terminology;
- Chapter I - redox reactions, Faraday's laws;
- Chapter II - Equilibrium electrochemistry:
cells, galvanic and electrolytic cells, thermodynamic state functions, theoretical cell voltage, half-cell / electrode potential, hydrogen
electrode, the electrochemical series, Nernst equation;
- Chapter III - Electrodes & interfaces:
  electrochemical potential, phase potentials, work function, Fermi level, the electrified interface, the electrochemical double layer, reference
electrodes and laboratory cells;
- Chapter IV - Electrolytes:
  conductivity, aqueous electrolytes, transference effects, liquid junctions, polymer electrolytes, ion-exchange membranes, Donnan
  exclusion, solid state ion conductors;
- Chapter V - Dynamic electrochemistry:
  overpotentials, description of charge-transfer reaction, Butler-Volmer and Tafel equation, exchange current density, mass transport
  limitations;
- Chapter VI - Industrial electrochemistry:
  electrochemical engineering, process and reactor types, current density distribution, porous electrodes, chlor-alkali and HCl electrolysis,
oxogen depolarized cathode;
- Chapter VII - Energy storage & conversion:
  important primary and secondary battery chemistries, fuel cells, polymer electrolyte fuel cells, low temperature H2 and O2 electrochemistry,
electrocatalysis, triple-phase boundary, solid oxide fuel cell, conversion efficiency;
- Chapter VIII - Electroanalytical methods & sensors:
  potentiometry, cyclic and stripping voltammetry, rotating disc electrode studies, electrochemical sensors;
- Chapter IX - Corrosion:
  Pourbaix diagram, corrosion potential, passivation, corrosion protection; Historical notes

Lecture notes

lecture notes, exercise & solutions (PDF files) via download website

Literature


Prerequisites / notice

Students should be familiar with the fundamentals of physical chemistry.

Taught
cOMPETENCIES

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

assessed

assessed

Number

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0745-01L</td>
<td>General and Environmental Toxicology</td>
<td>W</td>
<td>6</td>
<td>3V</td>
</tr>
<tr>
<td>529-0745-01L</td>
<td>Molecular Aspects of Catalysts and Surfaces</td>
<td>W</td>
<td>6</td>
<td>4G</td>
</tr>
</tbody>
</table>

Autumn Semester 2021

Techniques and Technologies

Tableau

Systems and Process Engineering

Number

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0109-00L</td>
<td>Turbulent Flows</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
</tr>
</tbody>
</table>

Turbulent Flows
- Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings. Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows

Domain A - Subject-specific Competencies

Educational basis: basic chemistry, biology and biochemistry

Models and Simulations

Methods which are covered embrace: Gas adsorption and surface area analysis, IR-Spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy, X-ray absorption, solid state NMR, Electron Microscopy and others.

Domain A - Subject-specific Competencies

Techniques and Technologies

assessed
Classical Simulation of (Bio)Molecular Systems

W 6 credits 4G
P. H. Hünemenger, J. Dolenc, S. Rinker

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Introduction to classical (atomic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

ECTS

Principles of Macroeconomics

W 3 credits 2V
J.-E. Sturm

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

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

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society’s resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.


This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

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

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Negotiation: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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### 363-0503-00L Principles of Microeconomics

*W* 3 credits 2G M. Filippini

**Abstract**
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

**Objective**
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

**Content**
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

**Lecture notes**
Lecture notes, exercises and reference material can be downloaded from Moodle.

**Literature**
The book can also be used for the course ‘Principles of Microeconomics’ (Sturm)

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

**Complementary**

**Prerequisites / notice**
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
The course is focused on the design of Chemical Processes, with emphasis on the preliminary stages of the design approach, where existing chemical needs and unmet technical challenges are analyzed. We then develop the skills to critically analyze a specific chemical idea, rapidly test feasibility or chance for success and eventually realize its manufacturing. The chemical engineering basics are then used to assess performance of products or devices with non-traditional functions based on dynamic properties (e.g., responsive building materials; personal medical diagnostics on paper strips). The course teaches the interface between laboratory and market with a specific focus on evaluating the chemical value of a given process or compound, and the necessary steps to pursue the resulting project within an entrepreneurial environment. We therefore extend the questions of process design (how do we make something?) to the question of what should we make?

This course starts with analyzing existing chemical needs and unmet technical challenges. We then develop the skills to critically analyze a specific chemical idea for a product, to rapidly test feasibility or chance for success and to eventually realize its manufacturing. The chemical engineering basics are then used to assess performance of products or devices with non-traditional functions based on dynamic properties (e.g., responsive building materials; personal medical diagnostics on paper strips). The course teaches the interface between laboratory and market with a specific focus on evaluating the chemical value of a given process or compound, and the necessary steps to pursue the resulting project within an entrepreneurial environment. We therefore extend the questions of process design (how do we make something?) to the question of what should we make?

The 'Chemical Product Design' course teaches students quantitative concepts to analyze, select and transform theoretical concepts from chemistry and engineering into valuable real-world products. Basic chemistry and chemical engineering knowledge is required (Diffusion, Thermodynamics, Kinetics, ...).

Students are expected to actively develop chemical products along the course. Contributions will be made individually, or in small groups, where a larger topic is studied.


Prerequisites / notice

Prerequisites: Basic chemistry and chemical engineering knowledge (Diffusion, Thermodynamics, Kinetics, ...).

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications. A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.

### Catalysis and Separation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>W</td>
<td>6</td>
<td>3+1U</td>
<td>M. Mazzotti, V. Becattini</td>
</tr>
</tbody>
</table>

**Abstract**

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.

**Objective**

The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.
The class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.

Lecture notes
Handouts during the class

Literature
Recommendations for text books will be covered in the class

Prerequisites / notice
Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

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

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

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

529-0617-01L Catalysis Engineering W 6 credits 3G J. Pérez-Ramírez, S. J. Mitchell

Abstract
The purpose of the "Catalysis Engineering" course is to provide students with tools that enable the optimal design of catalytic materials and reactor engineering concepts favoring more sustainable manufacturing processes within the chemical industry.

Objective
The course aims at illustrating, from conception to implementation, the design of sustainable catalytic processes by integration of the microlevel (catalyst), mesolevel (reactor), and macrolevel (process). The word "sustainable" implies intensified processes with an improved exploitation of raw materials, wider use of renewable feedstocks, reduction of energy consumption, and minimized environmental impact.

By the use of modern case studies of industrial relevance, aspects of catalyst preparation and characterization, kinetics, mass and heat transport, and deactivation are discussed. Emphasis is put on understanding the interaction among these basic elements in order to select the optimal catalytic process. Since no textbooks covering this area are available at this time and the intention of this course is unique, the lectures will be based on own texts and journal articles. During the course, there will be specific topics addressed by industrial contributors.

Content
The following general aspects:
- Catalyst preparation and characterization
- Kinetics
- Mass and heat transport
- Selectivity
- Deactivation

will be demonstrated for modern catalytic materials and processes of industrial relevance such as:
- Chlorine recycling
- N2O abatement
- Chemoselective hydrogenations
- Hierarchical zeolite catalysts
- Syngas conversion
- Biomass to chemicals and fuels

Lecture notes
The course material is based on an own script, journal articles, and slides.

Prerequisites / notice
It is assumed that students selecting this course are familiar with general concepts of catalysis, reactor design, and transport phenomena.

GESS Science in Perspective
see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-CHAB.

Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-0016-AAL</td>
<td>Biology II</td>
<td>E-</td>
<td>2</td>
<td>4R</td>
<td>M. Stoffel</td>
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</tbody>
</table>

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

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

Abstract
The lecture course Biology II is a basic introductory course into biology for students who need to pass this course for admission to their MSc curriculum.

Objective
The objective of the lecture course Biology II is the understanding of form, function, and development of animals and of the basic underlying mechanisms.
The following numbers of chapters refer to the text-book "Biology" (Campbell & Reece, 7th edition, 2005) on which the course is based. Chapters 1-4 are a basic prerequisite. The sections "Structure of the Cell" (Chapters 5-10, 12, 17) and "General Genetics" (Chapters 13-16, 18, 46) are covered by the lecture Biology I.

1. Genomes, DNA Technology, Genetic Basis of Development
   - Chapter 19: Eukaryotic Genomes: Organization, Regulation, and Evolution
   - Chapter 20: DNA Technology and Genomics
   - Chapter 21: The Genetic Basis of Development

2. Form, Function, and Development of Animals I
   - Chapter 40: Basic Principles of Animal Form and Function
   - Chapter 41: Animal Nutrition
   - Chapter 44: Osmoregulation and Excretion
   - Chapter 47: Animal Development

3. Form, Function, and Development of Animals II
   - Chapter 42: Circulation and Gas Exchange
   - Chapter 43: The Immune System
   - Chapter 45: Hormones and the Endocrine System
   - Chapter 48: Nervous Systems
   - Chapter 49: Sensory and Motor Mechanisms

The following text-book is the basis for the courses Biology I and II:


The course content is based on the following chapters of the textbook Biochemistry (Berg, Tymoczko, Stryer, 7th edition, 2012, Freeman & Co, New York)

Chapter 1: The molecular design of life
Chapter 2: Protein composition and structure
Chapter 3: Exploring proteins and proteomes
Chapter 4: DNA, RNA and the flow of information
Chapter 5: Exploring Genes and Genomes
Chapter 7: Hemoglobin
Chapter 8: Enzymes and the basic concepts of catalysis
Chapter 11: Carbohydrates
Chapter 12: Lipids and cell membranes
Chapter 15: Metabolism: Basic concepts and design

The goal of this course is to give the students a basic understanding of the molecules that build a cell and make it function, and the basic principles of metabolism and molecular genetics

The lecture is a basic introductory course on the molecular principles of biology for students who need to pass this course for admission to their MSc curriculum.

The course content is based on the following chapters of the textbook Biochemistry (Berg, Tymoczko, Stryer, 7th edition, 2012, Freeman & Co, New York)
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective
The goal of this course is to provide students with a wide general understanding cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Content
The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Literature

Topic/Lecturer/Chapter/Pages: 
Analyzing cells & molecules / Gebhard Schertler/8/ 439-463; 
Membrane structure / Gebhard Schertler/ 10/ 565-595; 
Compartmentsorting/ Ulrike Kutay/12+14+6/641-694/755-758/782-783/315-320/325 -333/Table 6-2/Figure6-20, 6-21, 6-32, 6-34; 
Intracellular Membrane Traffic/ Ulrike Kutay/13/695-752; 
The Cytoskeleton/ Ulrike Kutay/ 15/889 - 948 (only the essentials); 
Membrane Transport of Small Molecules and the Electrical Properties of Membranes /Sabine Werner/11/597 - 633; 
Mechanisms of Cell Communication / Sabine Werner/15/813-876; 
Cancer/ Sabine Werner/20/1091-1141; 
Cell Junctions and Extracellular Matrix/Ueli Suter / 1035-1081; 
Stem Cells and Tissue Renewal/Ueli Suter /1217-1262; 
Development of Multicellular organisms/ Ernst Hafen/ 21/ 1145-1179 /1184-1198/1198-1213; 
Cell Migration/Joao Matos/951-960; 
Cell Cycle/chromosome segregation/Cell division/Meiosis/Joao Matos/ 963-1018.

Prerequisites / notice
none

Chemical and Bioengineering Master - Key for Type
<table>
<thead>
<tr>
<th>Key</th>
<th>Compulsory</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctorate</th>
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<tr>
<td>O</td>
<td>E-</td>
<td>Z</td>
<td>W</td>
<td>E-</td>
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Key for Hours

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

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
Chemical Engineering Bachelor

1. Semester

Compulsory Subjects First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0011-02L</td>
<td>General Chemistry (Inorganic Chemistry) I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Togni</td>
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<tr>
<td>- Abstract</td>
<td>Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions</td>
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<tr>
<td>- Objective</td>
<td>Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective</td>
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</tr>
<tr>
<td>- Content</td>
<td>Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Literature</td>
<td>Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.</td>
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<tr>
<td>- Taught competencies</td>
<td>Concepts and Theories assessed</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Taught competencies</td>
<td>Techniques and Technologies assessed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>529-0011-03L</td>
<td>General Chemistry (Organic Chemistry) I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U+1U</td>
<td>P. Chen</td>
</tr>
<tr>
<td>- Abstract</td>
<td>Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.</td>
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</tr>
<tr>
<td>- Objective</td>
<td>Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.</td>
<td></td>
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</tr>
<tr>
<td>- Content</td>
<td>Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, topicality, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromatics, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intermolecular interactions.</td>
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</tr>
<tr>
<td>- Lecture notes</td>
<td>Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>- Taught competencies</td>
<td>Concepts and Theories assessed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Taught competencies</td>
<td>Techniques and Technologies assessed</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>529-0011-01L</td>
<td>General Chemistry (Physical Chemistry) I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>H. J. Wörner</td>
</tr>
<tr>
<td>- Abstract</td>
<td>Die Vorlesung vermittelt eine Einführung in einige physikalischen Grundlagen der Chemie, insbesondere in die Radioaktivität, die Quantenmechanik, den Aufbau der Materie und eines Atoms, des Periodensystems der Elemente und die chemische Bindung.</td>
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</tr>
<tr>
<td>- Objective</td>
<td>Die Studierenden sind nach der Vorlesung in der Lage,</td>
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</tr>
<tr>
<td>- Objective</td>
<td>- mit für die Chemie wichtigen physikalischen Grössen und deren Einheiten zu rechnen,</td>
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<tr>
<td>- Objective</td>
<td>- einige Eigenschaften chemisch relevanter Teilchen zu benennen und experimentelle Methoden zur Bestimmung dieser Eigenschaften vorzuschlagen,</td>
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<tr>
<td>- Objective</td>
<td>- Anwendungen und Gefahren der Radioaktivität zu benennen,</td>
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<tr>
<td>- Objective</td>
<td>- radioaktive Zerfallsprozesse zu kategorisieren und den zeitlichen Verlauf von einfachen Zerfallsreaktionen mathematisch wiederzugeben sowie qualitativ vorherzusagen und darzustellen,</td>
<td></td>
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</tr>
<tr>
<td>- Objective</td>
<td>- Wellen- und Teilchenmaterie mit Hilfe der Quantenmechanik, der Wellenfunktion, Heisenbergsche Unschärferelation, Operatoren, Kommutatoren zu erklären und einfache Rechnungen damit auszuführen,</td>
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<tr>
<td>- Objective</td>
<td>- Absorptions- und Emissionsspektren von Einkristallen zu analysieren und zu berechnen,</td>
<td></td>
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</tr>
<tr>
<td>- Objective</td>
<td>- das Konzept eines Orbitals zu erklären und die qualitative Form der Orbitale des Wasserstoffatoms mathematisch und bildlich wiedergeben,</td>
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<tr>
<td>- Objective</td>
<td>- den Aufbau des Periodensystems der Elemente mit Hilfe des Orbitalkonzepts zu erklären,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Objective</td>
<td>- Ähnlichkeiten in der elektronischen Struktur von Atomen zu erkennen und zu benutzen, um chemisch relevante Eigenschaften vorherzusagen, und</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>- Objective</td>
<td>- Termsymbole für atomare Grundzustände aufzustellen,</td>
<td></td>
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</tr>
<tr>
<td>- Content</td>
<td>Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and symbols, Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger’s equation, the hydrogen atom, construction of the periodic table of the elements.</td>
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</tr>
<tr>
<td>- Content</td>
<td>Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.</td>
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</tr>
<tr>
<td>- Lecture notes</td>
<td>See homepage of the lecture.</td>
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</tr>
</tbody>
</table>

Autumn Semester 2021
Page 487 of 2152
Lecture: Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and

H. V. Schönberg
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids) Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

The lecture follows the book "Physics" by Paul A. Tipler.

O. not assessed
P. H. Hünenberger
Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor

2V+2U
Physics I
Practical Course General Chemistry
assessed
assessed
assessed
assessed
assessed

J. Home
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

L. Keller
Mathematical Foundations I: Analysis A

O 5 credits 3V+2U

L. Papula: Mathematik für Ingenieure und Naturwissenschaftler (3 Bände), Vieweg

further reading suggestions will be indicated during the lecture

Taught
competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed
Decision-making
not assessed

Domain C - Social Competencies
Communication
not assessed
Customer Orientation
not assessed

Domain D - Personal Competencies
Adaptability and Flexibility
not assessed
Creative Thinking
assessed

For more information about the lecture: www.csms.ethz.ch/education/InfoI

Lab. Course 402-0043-00L

Introduction to Computer Science

5 credits

Types of Time

Domain D - Personal Competencies

Prerequisites / notice

Voraussetzungen: Maturastoff. Insbesondere Integral- und Differentialrechnung.

529-0011-04L

Practical Course General Chemistry

Latest online enrolment is 20.9.2021

8 credits

H. V. Schönberg, E. C. Meister

Information about the practical course will be given on the first day.

Qualitative analysis (determination of cations and anions), acid-base-equilibria (pH-values, titrations, buffer), precipitation equilibria (gravimetry, potentiometry, conductivity), redoxreactions (syntheses, redox-titrations, galvanic elements), metal complexes (syntheses, complexometric titration).

Analysis of measured data, vapour pressure, conductivity, calorimetry, solubility.
Objective
Qualitative analysis (simple cation and anion separation process, determination of cations and anions), acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems, Kjeldahl determination), precipitation equilibria (gravimetry, potentiometry, conductivity), oxidation state and redox behaviour (syntheses), redox-titrations, galvanic elements, metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration) analysis of measured values (measuring error, average value, error analysis), states of aggregation (vapour pressure), characteristics of electrolytes (conductivity measurements), thermodynamics (calorimetry, solubility).

Content
The general aim for the students of the practical course in general chemistry is an introduction in the scientific work and to get familiar with simple experimental procedures in a chemical laboratory. In general, first experiences with the principal reaction behaviour of a variety of different substances will be made. The chemical characteristics of these will be elucidated by a series of quantitative experiments alongside with the corresponding qualitative analyses. In order to get an overview of classes of substances as well as some general phenomena in chemistry suitable experiments have been chosen. In the second part of the practical course, i.e. physical chemistry, the behaviour of substances in their state of aggregation as well as changes of selected physical values will be recorded and discussed.

Lecture notes
http://www.gruetzmacher.ethz.ch/education/labcourses

Literature
Moodle Lernplattform

Prerequisites / notice
Compulsory: online enrolment latest one week after start of the semester
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

3. Semester

Examination Block I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0121-00L</td>
<td>Inorganic Chemistry I</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>H. Grützmacher, P. Steinegger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals as well as the lanthanides and actinides. Introduction of methods of characterization, physical-chemical properties of coordination compounds as well as principles of radiochemistry.</td>
<td></td>
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<tr>
<td>Content</td>
<td>The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. The students will acquire knowledge on the fundamentals of radioactive decay and radiochemistry. Furthermore, they will be familiar with the basics of inorganic chemistry of lanthanides and actinides.</td>
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</tr>
<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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</tr>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
<td></td>
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</tr>
</tbody>
</table>

| 529-0221-00L    | Organic Chemistry I          | O    | 3 credits | 2V+1U      | H. Wennemers |
| Abstract        | Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions. |
| Content         | Acquisition of a basic repertoire of synthetic methods including important reactions of aldehydes, ketones, carboxylic acids and carboxylic acid derivatives, as well as eliminations and fragmentations. Particular emphasis is placed on the understanding of reaction mechanisms and the correlation between structure and reactivity. A deeper understanding of the concepts presented during the lecture is reached by solving the problems handed out each time and discussed one week later in the exercise class. |
| Literature      | No set textbooks. Optional literature will be proposed at the beginning of the class and in the lecture notes. |

| 529-0422-00L    | Physical Chemistry II: Chemical Reaction Kinetics | O    | 4 credits | 3V+1U      | F. Merkt, U. Hollenstein |
| Objective       | Introduction to Chemical Reaction Kinetics |

Content

Fundamental concepts: rate laws, elementary reactions and composite reactions, molecularity, reaction order. Experimental methods in reaction kinetics up to new developments in femtosecond kinetics. Simple chemical reaction rate theories: temperature dependence of the rate constant and Arrhenius equation, collision theory, reaction cross-section, transition state theory. Reaction mechanisms and complex kinetic systems, approximation techniques, chain reactions, explosions and detonations. Homogeneous catalysis and enzyme kinetics.

Experimental methods in reaction kinetics up to new developments in femtosecond kinetics. Simple chemical reaction rate theories: temperature dependence of the rate constant and Arrhenius equation, collision theory, reaction cross-section, transition state theory. Reaction mechanisms and complex kinetic systems, approximation techniques, chain reactions, explosions and detonations. Homogeneous catalysis and enzyme kinetics.

Literature


Prerequisites / notice

Voraussetzungen:
- Mathematik I und II
- Allgemeine Chemie I und II
- Physikalische Chemie I

529-0051-00L Analytical Chemistry I O 3 credits 3G D. Günther, M.-O. Ebert, G. Schwarz, R. Zenobi

Abstract

Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective

Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

Content

Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:

- Mass spectrometry: Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Chemical basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.
- UV/VIS spectroscopy: Basics, interpretation of electron spectra. Circular dichroism (CD) and optical rotation dispersion (ORD).

Lecture notes

Script will be for the production price

Literature

- M. Hesse, H. Meier, B. Zeeh, Spektroskopische Methoden in der organischen Chemie, 5. überarbeitete Auflage, Thieme, Stuttgart, 1995

Prerequisites / notice

Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

401-0373-00L Mathematics III: Partial Differential Equations O 4 credits 2V+1U A. Carlotto

Abstract


Objective

Classical tools to solve the most common linear partial differential equations.

Content

1) Examples of partial differential equations
- Classification of PDEs
- Superposition principle

2) One-dimensional wave equation
- D'Alembert's formula
- Duhamel's principle

3) Fourier series
- Representation of piecewise continuous functions via Fourier series
- Examples and applications

4) Separation of variables
- Solution of wave and heat equation
- Homogeneous and inhomogeneous boundary conditions
  - Dirichlet and Neumann boundary conditions

5) Laplace equation
- Solution of Laplace's equation on the rectangle, disk and annulus
- Poisson formula
- Mean value theorem and maximum principle

6) Fourier transform
- Derivation and definition
- Inverse Fourier transformation and inversion formula
- Interpretation and properties of the Fourier transform
- Solution of the heat equation

7) Laplace transform (if time allows)
- Definition, motivation and properties
- Inverse Laplace transform of rational functions
- Application to ordinary differential equations

Lecture notes

See the course web site (linked under Lernmaterialien)
Literature


Additional books:


4) E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1, 2, 11, 12, 6)

Prerequisites / notice

For additional sources, see the course web site (linked under Lernmaterialien)

Required background:

1) Multivariate functions: partial derivatives, differentiability, Jacobian matrix, Jacobian determinant

2) Multiple integrals: Riemann integrals in two or three variables, change of variables

2) Sequences and series of numbers and of functions

3) Basic knowledge of ordinary differential equations

Laboratory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0129-00L</td>
<td>Inorganic and Organic Chemistry II</td>
<td>O</td>
<td>11 credits</td>
<td>16P</td>
<td>V. Mougel</td>
</tr>
</tbody>
</table>

Abstract

Introduction to the experimental methods of Inorganic Chemistry

Objective

The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compounds are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Content

Emphasis is given to scientific writing (experiment reports).

Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds.

Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

Lecture notes

A manual is distributed in the teaching laboratory.

Prerequisites / notice

- Passed Basisprüfung
- Passed Practical Course General Chemistry (1. Semester, 529-0011-04)
- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230)
- Continuous Attendance of Course Inorg. Chemistry 1 (3. Sem., 529-0121) and Analytical Chemistry 1 (3. Sem., 529-0051)

If necessary, access priority will be settled according to the results of the first-year examinations.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

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

Domain C - Social Competencies

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

Domain D - Personal Competencies

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

5. Semester

Compulsory Subjects

Examination Block II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0557-00L</td>
<td>Chemical Engineering Thermodynamics</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>A. de Mello, S. Stavrakis</td>
</tr>
</tbody>
</table>
A primary objective of the course is to present a rigorous treatment of classical thermodynamics, whilst retaining a strong engineering perspective. Accordingly, real-world engineering examples will be used to highlight how thermodynamics is applied in engineering practice. The core ideas presented and developed within the course will provide a foundation for subsequent studies in such fields as fluid mechanics, heat transfer and statistical thermodynamics.

The first part of the course introduces the basic concepts and language of chemical engineering thermodynamics. This is followed by an analysis of energy and energy transfer, with a specific focus on the concept of work and the first law of thermodynamics. Next, the notion of a pure substance is introduced, with a discussion of the physics of phase-changes being presented. The description of pure substances is further developed through an analysis of the PVT behavior of fluids, equation of states, ideal and non-ideal gas behaviour and compressibility factors.

The second part of the course begins with a discussion of the use of the energy balance relation in closed systems that involve pure substances and then develops relations for the internal energy and enthalpy of ideal gases. Next, the second law of thermodynamics is introduced, with a discussion of why processes occur in certain directions and why energy has quality as well as quantity. Applications to cyclic devices such as thermal energy reservoirs, heat engines and refrigerators are provided. Entropy changes that take place during processes for pure substances, incompressible substances and ideal gases are described.

The third part of the course establishes thermodynamic formulations for the calculation of enthalpy, internal energy and entropy as function of pressure and temperature. Gibbs energy, fugacity and chemical potential. Two-phase systems are introduced as well as the use of equations of state to construct the complete phase diagrams of pure fluid.

The final part of the course focuses on the properties of mixtures and the phase behavior of multicomponent systems. The fundamental equations of phase equilibria in terms of the chemical potential and fugacity are also discussed. The concept of an ideal solution is introduced and developed. This is followed by an assessment of non-ideal behavior and the use of activity coefficients for describing phase diagrams. Particular focus is given to phase equilibria. Finally, concepts relating to chemical equilibrium are introduced with the general concepts developed being applied to reacting species. Examples here include the calculation of the Gibbs free energy and the equilibrium constant of a reaction.

Lecture notes
Lecture handouts, background literature, problem sheets and notes will be made accessible to enrolled students through the lecture Moodle site.

Literature
Although there is not set text for the course, the following three texts will be used in part and are excellent introductions to Chemical Engineering thermodynamics:


Resources for the acquisition of material properties and data:

1. NIST Chemistry WebBook (https://webbook.nist.gov/chemistry/)

2. CRC Handbook of Chemistry & Physics, 99th Edition (http://hbcponline.com/)

A basic knowledge of chemical thermodynamics is required.

Prerequisites / notice

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

ECTS
4 credits

Lecture notes
Lecture notes will be handed out

Notice

Autumn Semester 2021
Homogeneous Reaction Engineering  O  4 credits  3G  P. Arosio

Abstract

Objective
Provide to the students a complete methodology for the analysis and design of homogeneous reactors

Content

Lecture notes
Scripts are available on line on the web page of the Morbidelli group.

Literature
J. Baldyga and J.R. Bourne, Turbulent Mixing and Chemical Reactions, John Wiley, 1999
A. Varma and M. Morbidelli, Mathematical Methods in Chemical Engineering, Oxford University Press, 1997

Microbiology  O  2 credits  2V  M. Ackermann, M. Schuppler, J. Vorholt-Zambelli

Abstract
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective
Teaching of basic knowledge in microbiology.

Content

Lecture notes
Wird von den jeweiligen Dozenten ausgegeben.

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

Statistical and Numerical Methods for Chemical Engineers  O  3 credits  2V+2U  R. Käppeli, P. Müller, A. Ruf, C.-J. Shih, M. Sokolov

Abstract
This course covers common numerical algorithms and statistical methods used by chemical engineers to solve typical problems arising in industrial and research practice. The focus is on application of these algorithms to real world problems, while the underlying mathematical principles are also explained. The MATLAB environment is adopted to integrate computation, visualization and programming.

Objective
Topics covered:

Part I: Numerical Methods:
- Interpolation & Numerical Calculus
- Non-linear Equations
- Ordinary Differential Equations
- Partial Differential Equations
- Linear and Non-linear Least Squares

Part II: Statistical Methods:
- Data analysis and regression methods
- Statistical experimental design
- Multivariate analysis of spectra

Lecture notes
For the numerics part, see http://www.sam.math.ethz.ch/~karoger/numci/2020/

Literature
Recommended reading:
4) W. A. Stahl, Statistische Datenanalyse, Vieweg, 4th edition 2002


Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

Content
In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

The course consists of several practice and theory sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.
Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |

>>> Examination Block IV

Offered in the Spring Semester.

>>> Examination Block V

Offered in the Spring Semester.

>>> Laboratory Courses and Case Studies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
The focus of part I of the case study course lies on the literature-based comparison of chemical process alternatives. Based on this compilation and selected quantitative as well as qualitative measures, a process assessment and comparison is conducted. A basic flowsheet is then generated, and mass and energy balances are performed to carry out a preliminary economic and environmental assessment.

Objective
- to obtain knowledge about different databases and sources of information
- application of the knowledge obtained in lectures to a real problem
- problem-oriented problem solving (application of different methods to the same subject)
- team work
- report writing and presentation techniques

Content
The focus of part I of the case study course lies on the literature-based comparison of chemical process alternatives. For this purpose, relevant substance data (i.e. physico-chemical, toxicological, safety, and environmental data), as well as information about synthesis routes and technical implementations (i.e. on reaction kinetics; possible separation operations; economic, safety, and environmental aspects), are collected from the literature. Based on this compilation and selected quantitative as well as qualitative measures, a process assessment and comparison is conducted and the most promising process alternative is chosen for further evaluation. For this alternative, a basic flowsheet and mass and energy balances are generated.

529-0639-01L | Chemical Engineering Laboratory | O    | 6 credits | 8P    | N. Kobert, R. Grass  

Abstract
Introduction to various tools of chemical engineering techniques with reference to the lectures. In groups of two, students will conduct experiments in the following areas: thermodynamics and phase equilibria including electrochemistry, transport phenomena, kinetics and selectivity of complex reactions, characterisation of ideal and real reactors.

Objective
Introduction to various tools of chemical engineering techniques with reference to the running lectures.

Content
In groups of two, students will conduct selected experiments in the following areas: thermodynamics and phase equilibria including electrochemistry, transport phenomena, kinetics and selectivity of complex reactions, characterisation of ideal and real reactors.

Prerequisites / notice
Safety conceptt: https://chab.ethz.ch/studium/bachelor1.html

► GESS Science in Perspective

►► Science in Perspective

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-CHAB

►► Language Courses

see GESS Science in Perspective: Language Courses ETH/UZH

Chemical Engineering Bachelor - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

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

Comparative and International Studies Master

Core Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>857-0001-00L</td>
<td>Methods I: Research Design, Qualitative Methods, and Data Collection</td>
<td>O</td>
<td>6 credits</td>
<td>2U+2S</td>
<td>S. Hegewald, F. Schimmelfennig</td>
</tr>
</tbody>
</table>

**Abstract**
The seminar covers basic issues of research design, small-n research, and data collection. It deals with issues of causality, conceptualization, case study design and QCA. Data collection includes interviews, surveys, text analysis, and experimental research.

**Objective**
This MACIS core seminar covers basic issues of research design, small-n research, and data collection. It familiarizes students with general research design problems such as defining research questions, analyzing causality, and designing single and comparative case studies. It then introduces them to basic issues in small-n research. Students acquire an understanding of the specific challenges and design problems in qualitative analysis. Finally, students are introduced to exemplary methods of data collection. By the end of the course, students should be able to use the principal methods of data collection used by political scientists, have a critical understanding of the advantages and disadvantages of the methods, and should be able to reflect on and discuss the methods in light of research questions of their interest.

<table>
<thead>
<tr>
<th>Taught competencies</th>
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</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
</tr>
<tr>
<td>Concepts and Theories</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
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<tr>
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<td>Domain C - Social Competencies</td>
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<td>Communication</td>
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<tr>
<td>Domain D - Personal Competencies</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<tbody>
<tr>
<td>857-0007-00L</td>
<td>Democracy</td>
<td>W</td>
<td>8 credits</td>
<td>2S</td>
<td>F. Schimmelfennig, D. Kübler</td>
</tr>
</tbody>
</table>

**Abstract**
The seminar focuses on seminal books and articles as well as brand new analyses on topical issues of democratic theory and practice. After reviewing theoretical models and different types of democracy, the seminar deals with core problems of democratic governance and with challenges to democracy stemming from globalization and international institutions.

**Objective**
At the end of the seminar, students are familiar with the relevant theoretical and empirical literature on democracy and democratization in national and international contexts. They are able to reflect on contemporary challenges to democracy, in particular those stemming from the internationalization of politics.

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>see <a href="http://www.cis.ethz.ch/education/macis/courses">http://www.cis.ethz.ch/education/macis/courses</a></td>
</tr>
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</thead>
<tbody>
<tr>
<td>857-0009-00L</td>
<td>Political Violence</td>
<td>W</td>
<td>8 credits</td>
<td>2S</td>
<td>L.-E. Cederman, G. D. Clayton</td>
</tr>
</tbody>
</table>

**Abstract**
This course offers an introduction to political violence in domestic and international politics. The course covers explanations of interstate wars, theories of civil and ethnic wars and regional conflict. Other topics include new threats, including transnational terrorist networks and other non-state actors, and the relationship between conflict and nation-building and democratization processes.

**Objective**
This course offers an introduction to political violence in domestic and international politics. The course covers explanations of interstate wars, theories of civil and ethnic wars and regional conflict. Other topics include new threats, including transnational terrorist networks and other non-state actors, and the relationship between conflict and nation-building and democratization processes.

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</tr>
</thead>
<tbody>
<tr>
<td>857-0091-00L</td>
<td>Methods II: Quantitative Methods</td>
<td>O</td>
<td>6 credits</td>
<td>2U+2S</td>
<td>D. Hangartner, A. Alrababa'h</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers basic issues of research design, small-n research, and data collection. It deals with issues of causality, conceptualization, case study design and QCA. Data collection includes interviews, surveys, text analysis, and experimental research.

**Objective**
This course covers basic issues of research design, small-n research, and data collection. It familiarizes students with general research design problems such as defining research questions, analyzing causality, and designing single and comparative case studies. It then introduces them to basic issues in small-n research. Students acquire an understanding of the specific challenges and design problems in qualitative analysis. Finally, students are introduced to exemplary methods of data collection. By the end of the course, students should be able to use the principal methods of data collection used by political scientists, have a critical understanding of the advantages and disadvantages of the methods, and should be able to reflect on and discuss the methods in light of research questions of their interest.

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**Research Seminars**

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<thead>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>857-0103-00L</td>
<td>Topics in Public Policy: Governing the Energy Transition</td>
<td>W</td>
<td>8 credits</td>
<td>2V+3S</td>
<td>T. Schmidt, S. Sewerin, N. Schmid</td>
</tr>
</tbody>
</table>

**Abstract**
This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socio-economic, and political perspectives and applies various theoretical concepts to specific aspects of governing the energy transition. On this basis, students develop their own research project and produce a research paper.

**Objective**
- To gain an overview of the history of the transition of large technical systems
- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions
- To develop knowledge on the role of policy and politics in energy transitions
- To develop own research question and address it in research paper
Content

Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the recent United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.

This course introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It then introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of public policy and policy change in governing the energy transitions, considering the role of political actors, institutions and policy feedback.

The course has a highly interactive (seminar-like) character. Students are expected to actively engage in the weekly discussions and to give a presentation (15-20 minutes) on one of the weekly topics during that particular session. In addition to weekly lectures and student presentations, students will write a research paper of approximately 6000 words.

The presentation and participation in the discussions will form one part of the final grade (20%), the final exam another (20%), with the research paper forming the rest (60%).

Lecture notes

Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

Literature

A reading list will be provided via moodle.ethz.ch at the beginning of the semester.

Prerequisites / notice

This course is intended for the MA Comparative International Studies programme.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
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<th>ECTS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>857-0104-00L</td>
<td>Topics in Public Policy: The Politics and Policies of International Migration</td>
<td>W</td>
<td>8 credits</td>
<td>3S</td>
<td>D. Hangartner</td>
</tr>
<tr>
<td>857-0052-00L</td>
<td>Comparative and International Political Economy</td>
<td>W</td>
<td>8 credits</td>
<td>2S</td>
<td>V. Koubi, E. K. Smith</td>
</tr>
<tr>
<td>857-0098-00L</td>
<td>The Politics of Cybersecurity</td>
<td>W</td>
<td>8 credits</td>
<td>2S</td>
<td>M. Dunn Cavelty, M. Leese</td>
</tr>
<tr>
<td>857-0106-00L</td>
<td>International Environmental Politics (with Research Paper)</td>
<td>W</td>
<td>8 credits</td>
<td>2V+3S</td>
<td>T. Bernauer, V. Koubi</td>
</tr>
<tr>
<td>860-0023-00L</td>
<td>International Environmental Politics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Bernauer</td>
</tr>
</tbody>
</table>

Electives

- Acquire skills for carrying out independent research and writing a research paper in the area of international environmental politics.
This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

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

This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units

2. Reading assignments, available via Moodle, for a few selected course units

3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

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To facilitate your planning, the course is organized in terms of weekly units.
Abstract
The course is designed to increase awareness of how cultural perceptions and power structures have influenced society and our understanding of and practice in aid. It promotes alternatives to aid as linear and progressive Eurocentric narrative. The course draws on different theoretical perspectives and scrutinizes practical examples of aid interventions and similar initiatives.

Objective
The course goes beyond awareness raising of personal cultural characteristics and recognizing cultural values within development concepts. It unfolds traces of colonialism and power structures in day to day live and the aid industry. It promotes searching and initiating alternatives to aid as a Eurocentric narrative. Participants get familiar with different theoretical perspectives on decoloniality and scrutinize practical examples of aid interventions and similar initiatives.

Content
- Decolonialism key terms and concepts
- Conceptions of and alternatives to development (cooperation)
- Cultural (self-) awareness, diversity
- The role of culture in aid / development cooperation
- Implications of decolonialism for aid policy making and practice

865-0070-00L The Private Sector and Development Organizations: Building Successful Alliances

Abstract
The following topics will be discussed: The political economy of the Corporate Social Responsibility discourse, voluntary governance regimes and development; theory of change and effectiveness of soft law approaches, PPPs: introducing concepts and taking stock of experience, analysis of private sector strategies from selected governance actors, engaging with the private sector.

Objective
This course seeks to increase the participants’ understanding of the multifaceted and dialectic relationships between civil society, governments and private sector. It equips participants with knowledge and tools required for a strategic interaction between private sector organizations and development agencies. The course enables participants to contribute effectively to policy debates on the role of private sector actors and development.

Prerequisites / notice
Students of the course must fulfill requirements specified on the homepage of NADEL.

Master's Thesis

857-0019-00L Master's Thesis Colloquium

Abstract
In this colloquium, students enrolled in the MACIS program first present and discuss research design and methods issues concerning their prospective MA theses. Towards the end of the semester they present preliminary findings from their MA thesis work.

Objective
It is the goal of the colloquium to help students with the initial steps of writing their master theses. During the colloquium, they will develop a relevant research question and hypotheses and select appropriate methods and data.

857-0021-00L Master's Thesis

Abstract
The Master Thesis is an independent piece of research on an issue in comparative and international politics. It combines theory, methods, and empirical work.

Objective
The Thesis should demonstrate the students' ability to conduct independent research on the basis of the theoretical and methodological knowledge acquired during the MA program.

Comparative and International Studies Master - Key for Type

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

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

Special students and auditors need special permission from the lecturers.

Computational Biology and Bioinformatics Master
More information at: https://www.cbb.ethz.ch/

Core Courses
Please note that the list of core courses is a closed list. Other courses cannot be added to the core course category in the study plan. Also the assignments of courses to core subcategories cannot be changed.
Students need to pass at least one course in each core subcategory. A total of 40 ECTS needs to be acquired in the core course category.

Bioinformatics
Please note that all Bioinformatics core courses are offered in the autumn semester

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>636-0009-00L</td>
<td>Evolutionary Dynamics</td>
<td>W</td>
<td>6</td>
<td>2V+1U+2A</td>
<td>N. Beerenwinkel</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Evolutionary dynamics is concerned with the mathematical principles according to which life has evolved. This course offers an introduction to mathematical modeling of evolution, including deterministic and stochastic models, with an emphasis on tumor evolution.</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>The goal of this course is to understand and to appreciate mathematical models and computational methods that provide insight into the evolutionary process in general and tumor evolution in particular. Students should analyze and evaluate models and their application critically and be able to design new models.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary stability, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.</td>
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<td></td>
<td>Prerequisites / notice</td>
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<tr>
<td></td>
<td>Taught competencies</td>
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<tr>
<td></td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
<td></td>
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</tr>
<tr>
<td>636-0017-00L</td>
<td>Computational Biology</td>
<td>W</td>
<td>6</td>
<td>3G+2A</td>
<td>T. Vaughan</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.</td>
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<td>Objective</td>
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<td>Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:</td>
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<td></td>
<td>* stochastic models in molecular evolution</td>
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<tr>
<td></td>
<td>* phylogenetic &amp; phylogenomic inference</td>
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<td></td>
<td>* maximum likelihood and Bayesian statistics</td>
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<td>Attendees will apply these concepts to a number of applications yielding biological insight into:</td>
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<td></td>
<td>* epidemiology</td>
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<td></td>
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<tr>
<td></td>
<td>* pathogen evolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* macroevolution of species</td>
<td></td>
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<tr>
<td></td>
<td>Content</td>
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<td>The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GNAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantity population dynamic processes (such as transmission in epidemiology or speciation &amp; extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, Influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Lecture slides will be available on moodle.</td>
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<tr>
<td></td>
<td>Literature</td>
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<tr>
<td></td>
<td>The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:</td>
<td></td>
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<tr>
<td></td>
<td>* Yang, Z. 2006. Computational Molecular Evolution.</td>
<td></td>
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<tr>
<td></td>
<td>* Drummond, A. &amp; Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.</td>
<td></td>
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</tr>
</tbody>
</table>

Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-Bisse students, we highly recommend the voluntary course „Introduction to Programming”, which takes place at D-Bisse from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d e, or working through the script provided as part of this R course.

For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d e, or working through the script provided as part of this R course.

262-6100-00L Evolutionary Genetics W 4 credits 3G external organisers
262-6110-00L Bioinformatics Algorithms W 4 credits 3G external organisers
401-6282-00L Statistical Analysis of High-Throughput Genomic and W 5 credits 3G H. Rehrauer, M. Robinson
Abstract
A range of topics will be covered, including basic molecular biology, genomics technologies and in particular, a wide range of statistical and computational methods that have been used in the analysis of DNA microarray and high throughput sequencing experiments.

Objective

- Understand the fundamental "scientific process" in the field of Statistical Bioinformatics
- Be equipped with the skills/tools to preprocess genomic data (Unix, Bioconductor, mapping, etc.) and ensure reproducible research (Sweave)
- Have a general knowledge of the types of problems and biological applications encountered with microarray and sequencing data
- Have the general knowledge of the range of statistical methods that get used with microarray and sequencing data
- Gain the ability to apply statistical methods/knowledge/software to a collaborative biological project
- Gain the ability to critically assess the statistical bioinformatics literature
- Write a coherent summary of a bioinformatics problem and its solution in statistical terms

Content
Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; Controlling error rates of statistical tests (FPR versus FDR versus FWER); limma (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

Lecture notes
Lecture notes, published manuscripts

Prerequisites / notice
Prerequisites: Basic knowledge of the programming language R, sufficient knowledge in statistics

Former course title: Statistical Methods for the Analysis of Microarray and Short-Read Sequencing Data

Biophysics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>262-6106-00L</td>
<td>Current Topics in Biophysics</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>external organisers</td>
</tr>
<tr>
<td>636-0104-00L</td>
<td>Biophysical Methods</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>D. J. Müller</td>
</tr>
</tbody>
</table>

Abstract
Students will be imparted knowledge in basic and advanced biophysical methods applied to problems in molecular biotechnology. The course is fundamental to applying the methods in their daily and advanced research routines. The students will learn the physical basis of the methods as well as their limitations and possibilities to address existing and future topics in molecular biotechnology.

Objective
Gain of interdisciplinary competence in experimental and theoretical research, which qualifies for academic scientific work (master's or doctoral thesis) as well as for research in a biotechnology or a pharmaceutical company. The module is of general use in courses focused on modern biomolecular technologies, systems biology and systems engineering.

Content
The students will learn basic and advanced knowledge in applying biophysical methods to address problems and overcome challenges in biotechnology, cell biology and life sciences in general. The biological and physical possibilities and limitations of the methods will be discussed and critically evaluated. By the end of the course the students will have assimilated knowledge on a portfolio of biophysical tools widening their research capabilities and aptitude.

The biophysical methods to be taught include:
- Light microscopy: Resolution limit of light microscopy, fluorescence, GFP, fluorescence microscopy, DIC, phase contrast, difference between wide-field and confocal microscopy
- Super resolution optical microscopy: STED, PALM, STORM, other variations
- Electron microscopy: Scanning electron microscopy; transmission electron microscopy, electron tomography, cryo-electron microscopy, single particle analysis and averaging, tomography, sectioning, negative stain
- X-ray, electron and neutron diffraction
- MRI Imaging
- Scanning tunnelling microscopy and atomic force microscopy
- Patch clamp techniques: Principles of patch clamp analysis and application. Various patch clamp approaches used in research and industry
- Surface plasmon resonance-based biosensors
- Molecular pore-based sensors and sequencing devices
- Mechanical molecular and cellular assembly devices
- Optical and magnetic tweezers
- CD spectroscopy
- Optogenetics
- Molecular dynamics simulations

Lecture notes
Hand out will be given to students at lecture.

Literature
Methods in Molecular Biophysics (5th edition), Seryuky et al., Cambridge University Press
Bioanalytics, Lottspeich & Engels, Wiley VCH

Prerequisites / notice
The module is composed of 3 SWS (3 hours/week): 2-hour lecture, 1-hour seminar. For the seminar, students will prepare oral presentations on specific in-depth subjects with/under the guidance of the teacher.
The course enables students to formulate, analyse, and simulate mathematical models of biochemical networks. To this end, the course provides an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks. Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides all lecture material will be made available online.

Prerequisites / notice
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

### Computational Systems Biology

**Number** 636-0007-00L  
**Title** Computational Systems Biology  
**Type** W  
**ECTS** 6 credits  
**Hours** 3V+2U  
**Lecturers** J. Stelling

**Abstract** Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

**Objective** The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

**Content** Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

**Lecture notes** http://www.csb.ethz.ch/education/lectures.html

**Literature**


### Spatio-Temporal Modelling in Biology

**Number** 636-0706-00L  
**Title** Spatio-Temporal Modelling in Biology  
**Type** W  
**ECTS** 4 credits  
**Hours** 3G  
**Lecturers** D. Iber

**Abstract** This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

**Objective** Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

**Content**

1. Introduction to Modelling in Biology  
2. Morphogen Gradients  
3. Dynamical Systems  
4. Cell-cell Signalling (Dr Boaretto)  
5. Travelling Waves  
6. Turing Patterns  
7. Chemotaxis  
8. Mathematical Description of Growing Biological Systems  
9. Image-Based Modelling  
10. Tissue Mechanics  
11. Cell-based Tissue Simulation Frameworks  
12. Plant Development (Dr Dumont)  
13. Growth Control  
14. Summary

**Lecture notes** All lecture material will be made available online https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html

**Literature** The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

- Murray, Mathematical Biology, Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al. Computational Cell Biology, Springer
- Szalasal et al, System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Keerzig, Engineering Mathematics, Wiley

### Mathematical Modelling for Bioengineering and Systems Biology

**Number** 636-0117-00L  
**Title** Mathematical Modelling for Bioengineering and Systems Biology  
**Type** W  
**ECTS** 4 credits  
**Hours** 3G  
**Lecturers** D. Iber

**Abstract** Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

**Objective** Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

**Content** Basic concepts and mathematical tools to explore biochemical reaction kinetics and biological network dynamics. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

**Lecture notes** All lecture material will be made available online https://www.bsse.ethz.ch/cobi/teaching/636-0117-00L_Mathematical_Modelling_for_Bioengineering_and_Systems_Biology.html

**Literature** The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

- Murray, Mathematical Biology, Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al. Computational Cell Biology, Springer
- Szalasal et al, System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Keerzig, Engineering Mathematics, Wiley

**Prerequisites / notice** The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

Data Science

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>636-0018-00L</td>
<td>Data Mining I</td>
<td>W</td>
<td>6</td>
<td>3G+2A</td>
<td>K. M. Borgwardt</td>
</tr>
</tbody>
</table>

**Abstract**
Data Mining, the search for statistical dependencies in large databases, is of utmost importance in modern society, in particular in biological and medical research. This course provides an introduction to the key problems, concepts, and algorithms in data mining, and the applications of data mining in computational biology.

**Objective**
The goal of this course is that the participants gain an understanding of data mining problems and algorithms to solve these problems, in particular in biological and medical applications.

**Content**
The goal of the field of data mining is to find patterns and statistical dependencies in large databases, to gain an understanding of the underlying system from which the data were obtained. In computational biology, data mining contributes to the analysis of vast experimental data generated by high-throughput technologies, and thereby enables the generation of new hypotheses.

In this course, we will present the algorithmic foundations of data mining and its applications in computational biology. The course will feature an introduction to popular data mining problems and algorithms, reaching from classification via clustering to feature selection. This course is intended for both students who are interested in applying data mining algorithms and students who would like to gain an understanding of the key algorithmic concepts in data mining.

Tentative list of topics:

1. Distance functions
2. Classification
3. Clustering
4. Feature Selection

**Lecture notes**
Course material will be provided in form of slides.

**Literature**
Will be provided during the course.

**Prerequisites / notice**
Basic understanding of mathematics, as taught in basic mathematics courses at the Bachelor's level.

252-0535-00L Advanced Machine Learning

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<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
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</tbody>
</table>

**Abstract**
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.

**Literature**

**Prerequisites / notice**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Seminar

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>636-0704-00L</td>
<td>Computational Biology and Bioinformatics Seminar</td>
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<td>2S</td>
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</table>

The seminar is addressed primarily at students enrolled in the MSc CBB programme. Students of other ETH study programmes interested in

Autumn Semester 2021

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this course need to ask the lecturer for permission to enrol in the course.

The Seminar will be offered in autumn semester in Basel (involving professors and lecturers from the University of Basel) and in spring semester in Zurich (involving professors and lecturers from the University of Zurich). Professors and lecturers from ETH Zurich are involved in both semesters.

Abstract
Computational biology and bioinformatics aim at an understanding of living systems through computation. The seminar combines student presentations and current research project presentations to review the rapidly developing field from a computer science perspective. Areas: DNA sequence analysis, proteomics, optimization and bio-inspired computing, and systems modeling, simulation and analysis.

Objective
Studying and presenting fundamental papers of Computational Biology and Bioinformatics. Learning how to make a scientific presentation and how classical methods are used or further developed in current research.

Content
Computational biology and bioinformatics aim at advancing the understanding of living systems through computation. The complexity of these systems, however, provides challenges for software and algorithms, and often requires entirely novel approaches in computer science. The aim of the seminar is to give an overview of this rapidly developing field from a computer science perspective. In particular, it will focus on the areas of (i) DNA sequence analysis, sequence comparison and reconstruction of phylogenetic trees, (ii) protein identification from experimental data, (iii) optimization and bio-inspired computing, and (iv) systems analysis of complex biological networks. The seminar combines the discussion of selected research papers with a major impact in their domain by the students with the presentation of current active research projects/open challenges in computational biology and bioinformatics by the lecturers. Each week, the seminar will focus on a different topic related to ongoing research projects at ETHZ, University of Basel and University of Zurich, thus giving the students the opportunity of obtaining knowledge about the basic research approaches and problems as well as of gaining insight into (and getting excited about) the latest developments in the field.

Literature
Original papers to be presented by the students will be provided in the first week of the seminar.

Advanced Courses
A total of 30 ECTS needs to be acquired in the Advanced Courses category. Thereof at least 16 ECTS in the Theory and at least 10 ECTS in the Biology category.

Note that some of the lectures are being recorded: https://video.ethz.ch/lectures.html

Theory
At least 18 ECTS need to be acquired in this category.

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<th>Number</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>401-0663-00L</td>
<td>Numerical Methods for Computer Science</td>
<td>W</td>
<td>7 credits</td>
<td>2V+2U+2P</td>
<td>R. Hiptmair</td>
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</tbody>
</table>

Abstract
The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.

Objective
- Knowledge of the fundamental algorithms in numerical mathematics
- Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms
- Ability to choose the appropriate numerical method for concrete problems
- Ability to interpret numerical results
- Ability to implement numerical algorithms efficiently

Content
- Computing with Matrices and Vectors
  2.1 Fundamentals
  2.2 Software and Libraries
  2.4 Computational Effort
  2.5 Machine Arithmetic and Consequences
- Direct Methods for (Square) Linear Systems of Equations
  3.1 Introduction: Linear Systems of Equations (LSE)
  3.2 Theory: Linear Systems of Equations (LSE)
  3.5 Survey: Elimination Solvers for Linear Systems of Equations
  3.7 Sparse Linear Systems
- Direct Methods for Linear Least Squares Problems
  4.1 Least Squares Solution Concepts
  4.2 Normal Equation Methods
  4.3 Orthogonal Transformation Methods
  4.3.1 Transformation Idea
  4.3.2 Orthogonal/Unitary Matrices
  4.3.3 QR-Decomposition
  4.3.4 QR-Based Solver for Linear Least Squares Problems
  4.4 Singular Value Decomposition (SVD)
  4.5 SVD-Based Optimization and Approximation
- Filtering Algorithms
  5.1 Filters and Convolutions
  5.2 Discrete Fourier Transform (DFT)
  5.3 Fast Fourier Transform (FFT)
- Machine Learning of One-Dimensional Data (Data Interpolation and Data Fitting in 1D)
  6.1 Abstract Interpolation (AI)
  6.2 Global Polynomial Interpolation
  6.4 Splines
  6.7 Least Squares Data Fitting
- Iterative Methods for Non-Linear Systems of Equations
  9.2 Iterative Methods
  9.4 Finding Zeros of Scalar Functions
  9.5 Newton's Method in Rn
  9.7 Non-linear Least Squares
Topics covered in this course include:

**Analytical Competencies**
- Discrete-time signals and systems.
- Fourier- and z-Transforms.
- Frequency domain characterization of signals and systems.
- System assessment.

**Creative Thinking**
- Proof techniques and practices.

**8 credits**

The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in signals and systems. Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**263-5210-00L Probabilistic Artificial Intelligence**

**W 8 credits 3V+2U+2A**

**A. Krause**

**Abstract**
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

**Objective**
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics.

**Content**
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**
Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

**401-0647-00L Introduction to Mathematical Optimization**

**W 5 credits 2V+1U**

**D. Adjaiashvili**

**Abstract**
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

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

**Content**
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

**Literature**
Information about relevant literature will be given in the lecture.

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

**227-0225-00L Linear System Theory**

**W 6 credits 5G**

**A. Iannelli**

**Abstract**
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the basic mathematical properties by exciting a system with various types of signals.

**Objective**
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

**Content**
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

**Lecture notes**
Available on the course Moodle platform.

**Sufficient mathematical maturity, in particular in linear algebra, analysis.**

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

- Domain B - Method-specific Competencies
  - Analytical Competencies
  - Problem-solving

- Domain D - Personal Competencies
  - Critical Thinking
  - Integrity and Work Ethics

**151-0575-01L Signals and Systems**

**W 4 credits 2V+2U**

**A. Carron**

**Abstract**
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**
Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercises.

**Content**
Biology is becoming increasingly quantitative and mathematical modeling is now an integral part of biological research. In many biological processes, ranging from gene-expression to evolution, randomness plays an important role that can only be understood using stochastic models. This course will provide the students with a theoretical foundation for developing such stochastic models and analyzing stochastic biochemical reaction networks.

The topics discussed in the course include among others:

1. The mathematical representation of random phenomena: The probability space, properties of the probability measure, Independence of events, Conditional probability and Bayes formula, applications to parameter inference.
3. Convergence of Random Variables: Modes of convergence, Laws of large numbers, the central limit theorem, the law of the iterated logarithm, Applications to the analysis of cell population data.

While no specific textbook will be followed, much of the material and homework problems will be taken from the following books:


For the course, students are expected to have a good grasp of Linear Algebra and Multivariable Calculus. Basic knowledge of set theory will also be needed. Students should be prepared for advanced reasoning.

Control Systems I is helpful but not required.
This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4i), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4i)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:

- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

261-5112-00L  Algorithms and Data Structures for Population Scale Genomics

W 3 credits  2G  to be announced

Does not take place this semester. Number of participants limited to 30.

Objective

Research in Biology and Medicine have been transformed into disciplines of applied data science over the past years. Not only size and inherent complexity of the data but also requirements on data privacy and complexity of search and access pose a wealth of new research questions.

Content

This interactive course will explore the latest research on algorithms and data structures for population scale genomics applications and give insights into both the technical basis as well as the domain questions motivating it.

1) Algorithms and data structures for text and graph compression. Motivated through applications in compressive genomics, the course will cover succinct indexing schemes for strings, trees and general graphs, compression schemes for binary matrices as well as the efficient representation of haplotypes and genomic variants.

2) Stochastic data structures and algorithms for approximate representation of strings and graphs as well as sets in general. This includes winnowing schemes and minimizers, sketching techniques, (minimal perfect) hash functions, and hierarchical memory efficient query data structures.

3) Data structures supporting encryption and data privacy. As an extension to data structures discussed in the earlier topics, this will include secure indexing using homomorphic encryption as well as design for secure storage and distribution of data.

252-0834-00L  Information Systems for Engineers

W 4 credits  2V+1U  G. Fourny
Abstract

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality.
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc

Elementary knowledge of set theory and logics

Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Biology

At least 12 ECTS need to be acquired in this category.

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<td>529-0733-01L</td>
<td>Enzymes</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>D. Hilvert</td>
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</tbody>
</table>

Abstract

Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme-catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

Objective

Overview of enzymes, enzyme-catalyzed reactions and metabolic processes.

Content

Principles of enzymatic catalysis, enzyme kinetics, mechanisms of enzyme catalyzed reactions (group transfer reactions, carbon-carbon bond formation, eliminations, isomerisations and rearrangements), cofactor chemistry, enzymes in organic synthesis and the biosynthesis of natural products, catalytic antibodies.

Lecture notes

A script will not be handed out.
### Literature

General:

In addition, citations from the original literature relevant to the individual lectures will be assessed weekly.

### 551-0309-00L Concepts in Modern Genetics

| W | 6 credits | 4V | Y. Barral, D. Bopp, A. Hajnal, O. Voinnet |

*Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.*

*Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html*

**Abstract**
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Objective**
This course focuses on the concepts of classical and modern genetics and genomics.

**Content**
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

**Lecture notes**
Scripts and additional material will be provided during the semester.

### 551-0313-00L Microbiology (Part I)

| W | 3 credits | 2V | W.-D. Hardt, L. Eberl, J. Piel, M. Pilhofer |

*Abstract*
Advanced concept class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

*Objective*
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

*Content*
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Lecture notes**
Updated handouts will be provided during the class.

**Literature**
Current literature references will be provided during the lectures.

**Prerequisites / notice**
English. The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

### 551-0317-00L Immunology I

| W | 3 credits | 2V | M. Kopf, A. Oxenius |

*Abstract*
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

*Objective*
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

*Content*
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

**Lecture notes**
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"*

*Prerequisites / notice*
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Domain B - Method-specific Competencies
  - Analytical Competencies: not assessed
  - Decision-making: assessed
  - Media and Digital Technologies: not assessed
  - Problem-solving: assessed
  - Project Management: not assessed

- Domain C - Social Competencies
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: assessed
  - Negotiation: not assessed

- Domain D - Personal Competencies
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: not assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

### 636-0105-00L Introduction to Biological Computers

| W | 4 credits | 3G | Y. Benenson |

*Abstract*
Biological computers are man-made biological networks that interrogate and control cells and organisms in which they operate. Their key features, inspired by computer science, are programmability, modularity, and versatility. The course will show how to rationally design, implement and test biological computers using molecular engineering, DNA nanotechnology and synthetic biology.
The course has the following objectives:

* Familiarize students with parallels between theories in computer science and engineering and information-processing in live cells and organisms

* Introduce basic theories of computation

* Introduce approaches to creating novel biological computing systems in non-living environment and in living cells including bacteria, yeast and mammalian/human cells.

The covered approaches will include
- Nucleic acids engineering
- DNA and RNA nanotechnology
- Synthetic biology and gene circuit engineering
- High-throughput genome engineering and gene circuit assembly

* Equip the students with computer-aided design (CAD) tools for biocomputing circuit engineering. A number of tutorials will introduce MATLAB SimBiology toolbox for circuit design and simulations

* Foster creativity, research and communication skills through semester-long “Design challenge” assignment in the broad field of biological computing and biological circuit engineering.
Content

Note: the exact subjects can change, the details below should only serve for general orientation

Lecture 1. Introduction: what is molecular computation (part I)?
* What is computing in general?
* What is computing in the biological context (examples from development, chemotaxis and gene regulation)
* The difference between natural computing and engineered biocomputing systems

Lecture 2: What is molecular computation (part II) + State machines
1st hour
* Detailed definition of an engineered biocomputing system
* Basics of characterization
* Design challenge presentation

2nd hour
* Theories of computation: state machines (finite automata and Turing machines)

Lecture 3: Additional models of computation
* Logic circuits
* Analog circuits
* RAM machines

Basic approaches to computer science notions relevant to molecular computation. (i) State machines; (ii) Boolean networks; (iii) analog computing; (iv) distributed computing. Design Challenge presentation.

Lecture 4. Classical DNA computing
* Adleman experiment
* Maximal clique problem
* SAT problem

Lecture 5: Molecular State machines through self-assembly
* Tiling implementation of state machine
* DNA-based tiling system
* DNA/RNA origami as a spin-off of self-assembling state machines

Lecture 6: Molecular State machines that use DNA-encoded tapes
* Early theoretical work
* Tape extension system
* DNA and enzyme-based finite automata for diagnostic applications

Lecture 7: Introduction to cell-based logic and analog circuits
* Computing with (bio)chemical reaction networks
* Turing computation with ultrasensitivity and cooperativity
* Specific examples

Lecture 8: Transcriptional circuits I
* Introducing transcription-based circuits
* General features and considerations
* Guidelines for large circuit construction

Lecture 9: Transcriptional circuits II
* Large-scale distributed logic circuits in bacteria
* Toward large-scale circuits in mammalian cells

Lecture 10: RNA circuits I
* General principles of RNA-centered circuit design
* Riboswitches and sRNA regulation in bacteria
* Riboswitches in yeast and mammalian cells
* General approach to RNAi-based computing

Lecture 11: RNA circuits II
* RNAi logic circuits
* RNAi-based cell type classifiers
* Hybrid transcriptional/posttranscriptional approaches

Lecture 12: In vitro DNA-based logic circuits
* DNAzyme circuits playing tic-tac-toe against human opponents
* DNA brain

Lecture 13: Advanced topics
* Engineered cellular memory
* Counting and sequential logic
* The role of evolution
* Fail-safe design principles

Benenson, Y. Biocomputers: from test tubes to live cells. Molecular Biosystems 2009, 5:675-685


Basic knowledge of molecular biology is assumed.

<table>
<thead>
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<th>Title</th>
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<th>Type</th>
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<td>636-0510-00L</td>
<td>Proteomics and Drug Discovery Research</td>
<td>W 2</td>
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<td>636-0511-00L</td>
<td>Developmental Neuroscience</td>
<td>W 2</td>
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<td>262-6170-00L</td>
<td>Molecular Mechanisms of Development</td>
<td>W 2</td>
<td>2V</td>
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<td>Molecular Control of Vertebrate Development and Organogenesis</td>
<td>W 2</td>
<td>2V</td>
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<tr>
<td>262-5130-00L</td>
<td>Evolutionary Medicine: Ancient Pathogens and Technologies (University of Zurich)</td>
<td>W 6</td>
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<td>University lecturers</td>
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<td>W 1</td>
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<td>W 2</td>
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<td>262-6105-00L</td>
<td>Frontiers in RNA Biology</td>
<td>W 2</td>
<td>2V</td>
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<td>636-0109-00L</td>
<td>Stem Cells: Biology and Therapeutic Manipulation</td>
<td>W 4</td>
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</table>

Abstract
Stem cells are central in tissue generation and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering, and novel technologies relevant for stem cell research and therapy will be discussed.

Objective
Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.

Content
We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

636-0108-00L Biological Engineering and Biotechnology

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content
1. Insight Into The Mammalian Cell Cycle. Cycling. The Balance Between Proliferation and Cancer - Implications For Biopharmaceutical Manufacturing

Lecture notes
Handout during the course.
Principles of Evolution: Theory (University of Zurich) W 6 credits 3V University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: BIO351

Abstract

"Nothing in Biology Makes Sense Except in the Light of Evolution". Evolutionary theory and methods are essential in all branches of modern biology.

Objective

Subject specific skills:
By the end of the course, students will be able to:
o describe basic evolutionary theory and its applications
o discuss ongoing debates in evolutionary biology
o critically assess the presentation of evolutionary research in the popular media

Key skills:
By the end of the course, students will be able to:
o approach biological questions from an evolutionary perspective

Content

This course will provide a broad overview of current evolutionary thought, including the mechanisms of evolutionary change, adaptation and the history of life and will involve practical field and lab work as well as lecture material.

Molecular and Structural Biology I: Protein Structure and Function

D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course.

Abstract

Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective

Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes

Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature

Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

Lab Rotations

Students starting before Autumn Semester 2021:
18 ECTS in total (262-01*).
At least two lab rotations need to be completed in two different research groups (supervisors).
Either choose Lab Rotation Short 1 (6 ECTS), Lab Rotation Short 2 (6 ECTS) and Lab Rotation Short 3 (6 ECTS)
Or choose Lab Rotation Long 1 (9 ECTS) and Lab Rotation Long 2 (9 ECTS)
Or choose Lab Rotation Short 1 (6 ECTS) and Industry Internship (12 ECTS)
Or choose Lab Rotation Short 1 (6 ECTS) and Lab Rotation Long 3 (12 ECTS)

Students starting in Autumn Semester 2021 or later:
18 ECTS in total (262-03*).
At least one lab rotation in different group/supervisor than master's thesis.
Either choose Lab Rotation Short 1 and Lab Rotation Short 2 (each 6 weeks, 9 ECTS)
Or choose lab Rotation Short 1 and Industry Internship Short (each 6 weeks, 9 ECTS)
Or choose Lab Rotation Long (12 weeks, 18 ECTS)
Or choose Industry Internship Long (12 weeks, 18 ECTS)

Industry internship of at least 8 weeks, completed with a written report.
The Master Thesis is the result of an independent scientific research and/or constructive development project in the chosen area of specialization. Students gain experience in an industrial environment and an overview of different research areas by applying concepts taught in the core courses and advanced courses.

262-0106-00L Lab Rotation Long 3
- W 12 credits 26A Lecturers
- Objective: Students gain an overview of different research areas by applying concepts taught in the core courses and advanced courses.

262-0300-00L Lab Rotation Short 1
- W 9 credits 17A Lecturers
- Objective: Students gain an overview of different research areas by applying concepts taught in the core courses and advanced courses.

262-0301-00L Lab Rotation Short 2
- W 9 credits 17A Lecturers
- Objective: Students gain an overview of different research areas by applying concepts taught in the core courses and advanced courses.

262-0303-00L Lab Rotation Long
- W 18 credits 34A Lecturers
- Objective: Students gain an overview of different research areas by applying concepts taught in the core courses and advanced courses.

262-0302-00L Industry Internship Short
- W 9 credits 17A Lecturers
- Objective: Industry internship of at least 6 weeks, completed with a written report.

262-0304-00L Industry Internship Long
- W 18 credits 34A Lecturers
- Objective: Industry internship of at least 12 weeks, completed with a written report.

GESS Science in Perspective
- see GESS Science in Perspective: Language Courses
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended GESS Science in Perspective (Type B) for D-INFK.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>262-0800-00L Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Professors</td>
<td></td>
</tr>
</tbody>
</table>
- Objective: The Master Thesis is the result of an independent scientific research and/or constructive development project in the chosen area of specialization.
- Abstract: The Master Thesis is the result of an independent scientific research and/or constructive development project in the chosen area of specialization.
- Content: The program concludes with a Master thesis that includes a written report and an oral presentation. The topic of the thesis can be chosen according to the student's interests in the field of computational biology & bioinformatics.
- Prerequisites / notice: Only students who fulfill the following criteria are allowed to begin with their master thesis:
  a. successful completion of the bachelor programme;
  b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Course Units for Additional Admission Requirements

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0002-AAL Data Structures and Algorithms</td>
<td>E-</td>
<td>8</td>
<td>15R</td>
<td>F. O. Friedrich Wicker</td>
<td></td>
</tr>
</tbody>
</table>
- Objective: An understanding of the design and analysis of fundamental algorithms and data structures. Knowledge regarding chances, problems and limits of parallel and concurrent programming. Deeper insight into a modern programming model by means of the programming language C++.
- Prerequisites / notice: Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.
- Abstract: This course is about fundamental algorithm design paradigms (such as induction, divide-and-conquer, backtracking, dynamic programming), classic algorithmic problems (such as sorting and searching), and data structures (such as lists, hashing, search trees). Moreover, an introduction to parallel programming is provided. The programming model of C++ will be discussed in some depth.
Content

Fundamental algorithms and data structures are presented and analyzed. Firstly, this comprises design paradigms for the development of algorithms such as induction, divide-and-conquer, backtracking and dynamic programming and classical algorithmic problems such as searching and sorting. Secondly, data structures for different purposes are presented, such as linked lists, hash tables, balanced search trees, heaps and union-find structures. The relationship and tight coupling between algorithms and data structures is illustrated with geometric problems and graph algorithms.

In the part about parallel programming, parallel architectures are discussed conceptually (multicore, vectorization, pipelining). Parallel programming concepts are presented (Amdahl’s and Gustavson’s laws, task/data parallelism, scheduling). Problems of concurrency are analyzed (Data races, bad interleavings, memory reordering). Process synchronisation and communication in a shared memory system is explained (mutual exclusion, semaphores, monitors, condition variables). Progress conditions are analysed (freedom from deadlock, starvation, lock- and wait-freedom). The concepts are underpinned with examples of concurrent and parallel programs and with parallel algorithms.

The programming model of C++ is discussed in some depth. The RAII (Resource Allocation is Initialization) principle will be explained. Exception handling, functors and lambda expression and generic programming with templates are further examples of this part. The implementation of parallel and concurrent algorithm with C++ is also part of the exercises (e.g. threads, tasks, mutexes, condition variables, promises and futures).

Literature


Prerequisites / notice

Please note that this is a self study (virtual) course, which implies that (in the autumn semester) there are no physical lectures or exercise sessions offered. If you want to attend the real course, please go to 252-0002-00L in the spring semester.

252-0856-AAL Computer Science E- 4 credits 9R F. O. Friedrich Wicker, R. Sasse

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

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

Abstract


Objective

Primäres Lernziel der Vorlesung ist die Befähigung zum Programmieren mit C++. Studenten beherrschen nach erfolgreichem Abschluss der Vorlesung die Mechanismen zum Erstellen eines Programms, sie kennen die fundamentalen Kontrollstrukturen, Datenstrukturen und verstehen, wie man ein algorithmisches Problem in ein Programm abbildet. Sie haben eine Vorstellung davon, was "hinter den Kulissen" passiert, wenn ein Programm übersetzt und ausgeführt wird.

Secondary Lernziele der Vorlesung sind das Computer-basierte, algorithmische Denken, Verständnis der Möglichkeiten und der Grenzen der Programmierung und die Vermittlung der Denkart eines Computerwissenschaftlers.

Content


Die Konzepte der Vorlesung werden jeweils durch Algorithmen und Anwendungen motiviert und illustriert.

Lecture notes

Ein Skript in englischer Sprache wird semesterbegleitend herausgegeben. Das Skript und die Folien werden auf der Vorlesungs homepage zum Herunterladen bereitgestellt.

Literature

Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010


406-0603-AAL Stochastics (Probability and Statistics) E- 4 credits 9R M. Kalisch

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

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

Abstract

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental statistical programming language *R*.

Content

From “Statistics for research” (online)

Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student’s t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"

Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation
262-0945-AAL  Cell and Molecular Biology for Engineers I and II  6 credits  13R  B. Treutlein

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

Abstract  The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Objective  After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content  Lectures will include the following topics: DNA, chromosomes, RNA, protein, genetics, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer, development and stem cells.


636-1005-AAL  Bio V: Bioinformatics  5 credits  7R  N. Beerewinkel

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

Literature  Pevsner J, Bioinformatics and Functional Genomics, 3rd edition, 2015, chapters 1–7

Computational Biology and Bioinformatics Master - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
<td></td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

Key for Hours

- Special students and auditors need special permission from the lecturers.
## Cyber Security Master

### Field of Specialization

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0463-00L</td>
<td>Security Engineering</td>
<td>W</td>
<td>7</td>
<td>2V+2U+2A</td>
<td>S. Krstic</td>
</tr>
</tbody>
</table>

**Abstract**

Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

**Objective**

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include:

- security requirements & risk analysis,
- system modeling and model-based development methods,
- implementation-level security, and
- evaluation criteria for the development of secure systems.
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

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The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
   - "Risk": assets, threats, vulnerabilities, risk
   - Risk assessment: quantitative and qualitative
   - Safeguards
   - Generic risk analysis procedure
   - The OCTAVE approach
   - Example of qualitative risk assessment
11. Threat modeling
   - Overview
   - Safety engineering basics: FMEA and FTA
   - Security impact analysis in the design phase
   - Modeling security threats: attack trees
   - Examples and experience
12. Evaluation criteria
   - NIST special papers
   - ISO/IEC 27000
   - Common criteria
   - BSI baseline protection
13. Guest lecture
   - TBA

Prerequisites / notice
Prerequisite: Class on Information Security

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, A. Perrig

Abstract
The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

The first part of the lecture covers individual system's aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include; patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

263-4640-00L Network Security

W 8 credits 2V+2U+3A A. Perrig, S. Frei, M. Legner, K. Paterson

Abstract

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content

The course will cover topics spanning four broad themes with a focus on the first two themes:

(1) network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;

(2) network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;

(3) analysis and inference topics such as traffic monitoring and network forensics; and

(4) new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L.

Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Objective

The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet routing and forwarding technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments, and even implement some of them on their own during labs and a final group project.

Content

The course will cover advanced topics in Internet routing and forwarding such as:

- Tunneling
- Hierarchical routing
- Traffic Engineering and Load Balancing
- Virtual Private Networks
- Quality of Service/Queuing/Scheduling
- Fast Convergence
- Network virtualization
- Network programmability (OpenFlow, P4)
- Network measurements

The course will be divided in two main blocks. The first block (~8 weeks) will interleave classical lectures with practical exercises and labs. The second block (~6 weeks) will consist of a practical project which will be performed in small groups (~3 students). During the second block, lecture slots will be replaced by feedback sessions where students will be able to ask questions and get feedback about their project. The last week of the semester will be dedicated to student presentations and demonstrations.

Lecture notes

Lecture notes and material will be made available before each course on the course website.

Literature

Relevant references will be made available through the course website.

Prerequisites / notice

Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed

227-0579-00L Hardware Security W 7 credits 2V+2U+2A K. Razavi

Abstract

This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures, reviewing and discussing papers, and executing some of these advanced attacks.

Objective

By the end of the course, the students will be familiar with the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Literature

Slides, relevant literature and manuals will be made available during the course.

Prerequisites / notice

Knowledge of systems programming and computer architecture is a plus.

252-0811-00L Applied Security Laboratory W 8 credits 7P C. Sprenger

Abstract

Hands-on course on applied aspects of information security. Applied information security, operating system security, OS hardening, computer forensics, web application security, project work, design, implementation, and configuration of security mechanisms, risk analysis, system review.

Objective

The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, logging), application security with an emphasis on web applications (web server setup, common web exploits, authentication, session handling, code security), computer forensics, and risk analysis and risk management.

Content

This course emphasizes applied aspects of Information Security. The students will study a number of topics in a hands-on fashion and carry out experiments in order to better understand the need for secure implementation and configuration of IT systems and to assess the effectiveness and impact of security measures. This part is based on a book and virtual machines that include example applications, questions, and answers.

The students will also complete an independent project: based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

Lecture notes


Literature

Recommended reading includes:
* Various: OWASP Guide to Building Secure Web Applications, available online
* O'Reilly, Loukides: Unix Power Tools, O'Reilly & Associates.
* Frisch: Essential System Administration, O'Reilly & Associates.
* NIST: Risk Management Guide for Information Technology Systems, available online as PDF
* BSI: IT-Grundschutzhandbuch, available online
Security of Wireless Networks

The reading list will be published on the course web site.

The Semester Project provides students with the opportunity to apply acquired knowledge and skills.

The course notes will be written in English.

Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection

This course is a detailed introduction to zero-knowledge proof protocols.

Links to relevant research papers will be given in the course materials.

Lecturers
S. Capkun, K. Kostiainen

252-1411-00L
Security of Wireless Networks

W 6 credits 2V+1U+2A

S. Capkun, K. Kostiainen

Objective
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

Content

263-4657-00L
Advanced Encryption Schemes

W 5 credits 2V+1U+1A

R. Gay

Objective
The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

Content
We will start by presenting the notion of Public-Key Encryption with its various security guarantees and some constructions. Then we will look into encryption schemes with fine-grained access control to the encrypted data, such as identity-based encryption or attribute-based encryption and present different methodology to prove their security.

Literature
Links to relevant research papers will be given in the course materials.

Prerequisites / notice
It is recommended for students to have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Applied Cryptography".

Seminar

263-4665-00L
Zero-Knowledge Proofs

W 5 credits 2V+1U+1A

J. Bootle

Objective
To understand various methods of constructing zero-knowledge proof protocols, and be able to analyse their security properties.

Content
The course will discuss interactive zero-knowledge proofs based on various commitment schemes, and explore connections to other areas like secure multi-party computation. The course may also describe some more advanced constructions of non-interactive proofs.

Lecture notes
The lecture notes will be written in English.

Prerequisites / notice
Students should have taken a first course in Cryptography (as taught in the Information Security course at Bachelor's level). Confidence with algebra and probability is desirable.

Semester Project

260-0100-00L
Semester Project

Only for Cyber Security MSc

W 12 credits 26A

Professors

The Semester Project provides students with the opportunity to apply acquired knowledge and skills.

Objective
The students can gain hand-on experience by solving independently a technical-scientific problem.

Prerequisites / notice
Prerequisites: At least one core course in Cyber Security and one inter focus course must have been completed successfully.

Minor

Data Management Systems

Core Courses
The course will cover the implementation aspects of data management systems using relational database engines as a starting point.

The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

Unfortunately, the quantity of data produced and available – now in the Zettabyte range (that’s 21 zeros) per year – keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today’s technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, …)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departments interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- “Information Systems for Engineers” (SOL, relational databases): this Fall
- “Big Data for Engineers” (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
Advanced topics in parallel and high-performance computing. The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing advanced machine learning algorithms.

Lecturers
J. M. Buhmann
C. Cotrini Jimenez

Advanced Machine Learning

252-0535-00L

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
- Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
- Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

System Security

252-1414-00L

Abstract
The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers individual system's aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Design of Parallel and High-Performance Computing

263-2800-00L

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.
Deep Learning

Number of participants limited to 320.

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Objective

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:

- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://i2l2.epfl.ch/courses/slt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

Prerequisites / notice

Machine Intelligence

Core Courses

Number Title Type ECTS Hours Lecturers
252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes: No lecture notes, but slides will be made available on the course webpage.

Literature:

Prerequisites / notice:
- The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
- PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms.

**Course Details**

**Title:** Natural Language Processing

**ECTS Credits:** 5

**Type:** W

**Hours:** 2V + 2U + 1A

**Prerequisites / notice:** Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

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**Number: 252-3005-00L**

**Title:** Natural Language Processing

**Type:** W

**ECTS Credits:** 5

**Hours:** 2V + 2U + 1A

**Lecturers:** R. Cotterell

**Abstract:** This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Objective:** The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

**Content:** This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Literature:** Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

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**Number: 261-5100-00L**

**Title:** Computational Biomedicine

**Type:** W

**ECTS Credits:** 5

**Hours:** 2V + 1U + 1A

**Lecturers:** V. Boeva, G. Rätsch

**Abstract:** The course critically reviews central problems in Biomedicine and discusses the technical foundations and solutions for these problems.

**Objective:** Over the past years, rapid technological advancements have transformed classical disciplines such as biology and medicine into fields of applied science. While the sheer amount of the collected data often makes computational approaches inevitable for analysis, it is the domain specific structure and close relation to research and clinic, that call for accurate, robust and efficient algorithms. In this course we will critically review central problems in Biomedicine and will discuss the technical foundations and solutions for these problems.

**Content:** The course will consist of three topic clusters that will cover different aspects of data science problems in Biomedicine:

1. **Statistical and algorithms models for efficient representation, search, comparison, composition and compression of large sets of strings, mostly originating from DNA or RNA Sequencing.**
2. **Statistical models and algorithms for the assessment and functional analysis of individual genomic variations.**
3. **Models for organization and representation of large scale biomedical data.**

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

**Prerequisites / notice:** Data Structures & Algorithms, Introduction to Machine Learning, Statistics/Probability, Programming in Python, Unix Command Line

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**Number: 263-2400-00L**

**Title:** Reliable and Trustworthy Artificial Intelligence

**Type:** W

**ECTS Credits:** 6

**Hours:** 2V + 2U + 1A

**Lecturers:** M. Vechev

**Abstract:** Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

- Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
- Defenses against attacks
- Combining gradient-based optimization with logic for encoding background knowledge
- Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
- Probabilistic certification of deep neural networks
- Training deep neural networks to be provably robust via automated reasoning
- Fairness (different notions of fairness, certifiably fair representation learning)
- Federated Learning (introduction, security considerations)

**Prerequisites / notice:** While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

For solving assignments, some programming experience in Python is expected.

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**Number: 263-4500-00L**

**Title:** Advanced Algorithms

**Type:** W

**ECTS Credits:** 9

**Hours:** 3V + 2U + 3A

**Lecturers:** M. Ghaffari, G. Zuzic

**Abstract:** This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Objective:** This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

**Content:** The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and rerandomization.

**Lecture notes:** https://people.inf.ethz.ch/gmohsen/AA21/

**Prerequisites / notice:** This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.
263-5005-00L Artificial Intelligence in Education

Number of participants limited to 75.

Abstract
Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective
The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class discussion, b) work on problem-sets exemplifying the use of educational data mining techniques, and c) undertake a final course project with feedback from instructors.

Content
The course will start with a general introduction to AI, where we will cover supervised and unsupervised learning techniques (e.g., classification and regression models, feature selection and preprocessing of data, clustering, dimensionality reduction and text mining techniques) with a focus on application of these techniques in educational data mining. After the introduction of the basic methodologies, we will continue with the most relevant applications of AI in educational technologies (e.g., intelligent tutoring and student personalization, scaffolding open-ended discovery learning, socially-aware AI and learning at scale with AI systems). In the final part of the course, we will cover challenges associated with using AI in student facing settings.

Lecture notes
Lecture slides will be made available at the course Web site.

Literature
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

Prerequisites / notice
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

263-5255-00L Foundations of Reinforcement Learning

Number of participants limited to 190.

Abstract
Reinforcement learning (RL) has been in the limelight of many recent breakthroughs in artificial intelligence. This course focuses on theoretical and algorithmic foundations of reinforcement learning, through the lens of optimization, modern approximation, and learning theory. The course targets M.S. students with strong research interests in reinforcement learning, optimization, and control.

Objective
This course aims to provide students with an advanced introduction into RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, the student will be able to:
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover "new" applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

Content
Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

Lecture notes
Lecture notes will be posted on Moodle.

Literature
Dynamic Programming and Optimal Control, Vol I & II, Dimitris Bertsekas
Algorithms for Reinforcement Learning, Csaba Csizmadia.

Prerequisites / notice
Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

263-5902-00L Computer Vision

Number of participants limited to 190.

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve these.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Theoretical Computer Science

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>A. Steger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Las Vegas &amp; Monte Carlo algorithms; inequalities of Markov, Chesonis, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks.</td>
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<tr>
<td>Objective</td>
<td>After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.</td>
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<tr>
<td>Content</td>
<td>Randomized Algorithms are algorithms that &quot;flip coins&quot; to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.</td>
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<tr>
<td>Lecture notes</td>
<td>Yes.</td>
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</tr>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
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</table>

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods

**Neural networks**

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PHD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

### Prerequisites

The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH. Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.

### Content

- **Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL)**
- **Polygon**
### Elective Courses

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</thead>
<tbody>
<tr>
<td>252-1407-00L</td>
<td>Algorithmic Game Theory</td>
<td>W</td>
<td>7</td>
<td>3V+2U+1A</td>
<td>P. Penna</td>
</tr>
<tr>
<td>Abstract</td>
<td>Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.</td>
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<tr>
<td>Objective</td>
<td>Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.</td>
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<tr>
<td>Content</td>
<td>The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don't care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes will be usually posted on the website shortly after each lecture.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Several copies of both books are available in the Computer Science library.</td>
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</tbody>
</table>

#### Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

| 227-0417-00L | Information Theory I                        | W    | 6    | 4G          | A. Lapidoth |
| Abstract     | This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity. |
| Objective    | The fundamentals of Information Theory including Shannon's source coding and channel coding theorems |
| Content      | The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity |
| Literature   | T.M. Cover and J. Thomas, Elements of Information Theory (second edition) |

| 401-3055-64L | Algebraic Methods in Combinatorics           | W    | 6    | 2V+1U       | B. Sudakov |
| Abstract     | Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. |
| Objective    | The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems. |
| Content      | Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools. One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications. |
| Lecture notes | The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757 |
| Prerequisites / notice | The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757 |

| 401-3901-00L | Linear & Combinatorial Optimization           | W    | 11   | 4V+2U       | R. Zenklusen |
| Abstract     | Mathematical treatment of optimization techniques for linear and combinatorial optimization problems. The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights. |

Content

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature


Prerequisites / notice

Solid background in linear algebra.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Visual and Interactive Computing

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>252-0543-01L</td>
<td>Computer Graphics</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td></td>
</tr>
</tbody>
</table>

Abstract

This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.

Objective

At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students’ curiosity to explore the field of computer graphics in subsequent courses or on their own.

Content

This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

Lecture notes

no

Literature

Books:
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in computer vision
- Physically Based Rendering: From Theory to Implementation

Prerequisites / notice

Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, Visual Computing course recommended.

The programming assignments will be in C++. This will not be taught in the class.

Elective Courses

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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0546-00L</td>
<td>Physically-Based Simulation in Computer Graphics</td>
<td>W</td>
<td>5</td>
<td>2V+1U+1A</td>
<td>V. da Costa Azevedo, B. Solenthaler, B. Thomaszewski</td>
</tr>
</tbody>
</table>
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

263-5905-00L Mixed Reality

Abstract
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human-machine interaction, as well as gaming technology.

Objective
After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

Content
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields, including:
- Introduction to Mixed Reality / Augmented Reality / Virtual Reality
- Introduction to 3D Computer Graphics, 3D Computer Vision.
This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Number Title Type ECTS Hours Lecturers
263-0006-00L Algorithms Lab W 8 credits 4P+3A A. Steger, E. Welzl

Number Title Type ECTS Hours Lecturers
263-0009-00L Information Security Lab W 8 credits 2V+1U+3P+1A K. Paterson, S. Capkun, D. Hofheinz, A. Perrig, S. Shinde

Number Title Type ECTS Hours Lecturers
260-0700-00L Internship E- 0 credits external organisers

Abstract
An internship provides opportunities to gain experience in an industrial environment and it creates a network of contacts.
### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>260-0800-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

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

1. Successful completion of the bachelor programme;
2. Fulfilling of any additional requirements necessary to gain admission to the master programme.*

#### Abstract

The Master's thesis concludes the study program and demonstrates the students' ability to use the knowledge and skills acquired during Master's studies to solve a complex cyber security problem.

#### Objective

To work independently and to produce a scientifically structured work.

### Cyber Security Master - Key for Type

<table>
<thead>
<tr>
<th>W</th>
<th>Eligible for credits</th>
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<tbody>
<tr>
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<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Dr</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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### Key for Hours

<table>
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<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</table>

<table>
<thead>
<tr>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS

European Credit Transfer and Accumulation System

*Special students and auditors need special permission from the lecturers.*
## Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>447-0649-01L</td>
<td>Applied Statistical Regression I</td>
<td>O</td>
<td>4</td>
<td>1V+1U</td>
<td>M. Tanadini</td>
</tr>
<tr>
<td></td>
<td>Only for DAS and CAS in Applied Statistics.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Simple and multiple regression models, with emphasis on practical aspects and interpretation of results, analysis of residuals and model selection.</td>
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<tr>
<td>447-0649-02L</td>
<td>Applied Statistical Regression II</td>
<td>O</td>
<td>2</td>
<td>1V+1U</td>
<td>C. Renaux</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Generalized linear models (GLMs) and basic ideas of more advanced regression models.</td>
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<tr>
<td>Objective</td>
<td>Understanding the concept and flexibility of generalized linear models and correct interpretation of the corresponding model outputs.</td>
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<tr>
<td>447-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design I</td>
<td>O</td>
<td>3</td>
<td>1V+1U</td>
<td>L. Meier</td>
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<tr>
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<td>Only for DAS and CAS in Applied Statistics.</td>
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<tr>
<td>Abstract</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs.</td>
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<tr>
<td>Objective</td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
<td>447-6201-00L</td>
<td>Nonparametric and Resampling Methods</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>L. Meier, D. Kuonen</td>
</tr>
<tr>
<td></td>
<td>Special Students &quot;University of Zurich (UZH)&quot; in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to <a href="mailto:registrar@ethz.ch">registrar@ethz.ch</a>. The Registrar's Office will then register you for the course.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.</td>
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<tr>
<td>Objective</td>
<td>For classical parametric models there exist optimal statistical estimators and test statistics whose distributions can often be determined exactly. The methods covered in this course allow for finding statistical procedures for more general models and to derive exact or approximate distributions of complicated estimators and test statistics.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This course is part of the programme for the certificate and diploma in Advanced Studies in Applied Statistics. It is given every second year in the winter semester break.</td>
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<tr>
<td>447-0990-00L</td>
<td>Workshop</td>
<td>O</td>
<td>1</td>
<td>1S</td>
<td>L. Meier</td>
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<td>Only for DAS in Applied Statistics.</td>
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<tr>
<td>Abstract</td>
<td>In the workshop each participant gives a short talk about a recent statistical problem encountered in their daily work.</td>
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<tr>
<td>Objective</td>
<td>Presentation of a statistical problem, getting to know different applications of statistical methodology.</td>
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</table>

## Electives

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>447-0625-02L</td>
<td>Applied Analysis of Variance and Experimental Design II</td>
<td>W</td>
<td>3</td>
<td>1V+1U</td>
<td>L. Meier</td>
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<tr>
<td></td>
<td>Only for DAS and CAS in Applied Statistics.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Participants will be able to plan and analyze sophisticated experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
<td>447-6221-00L</td>
<td>Nonparametric Regression</td>
<td>W</td>
<td>1</td>
<td>1G</td>
<td>M. Mächler</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course focusses on nonparametric estimation of probability densities and regression functions. These recent methods allow modelling without restrictive assumptions such as 'linear function'. These smoothing methods require a weight function and a smoothing parameter. Focus is on one dimension, higher dimensions and samples of curves are treated briefly. Exercises at the computer.</td>
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<tr>
<td>Objective</td>
<td>Knowledge on estimation of probability densities and regression functions via various statistical methods. Understanding of the choice of weight function and of the smoothing parameter, also done automatically. Practical application on data sets at the computer.</td>
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<tr>
<td>447-6257-00L</td>
<td>Repeated Measures</td>
<td>W</td>
<td>1</td>
<td>1G</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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</tbody>
</table>
This course introduces probabilistic deep learning (DL). DL is used for data with complex features like images. We treat DL as probabilistic.

**Objective**
Participants will gain the ability of recognizing repeated measures and to analyze them adequately. They will know how to deal with pseudoreplicates.

**Sampling Surveys**

- **W** 2 credits 1G
- **Abstract**
  The elements of a sample survey are explained. The most important classical sample designs (simple random sampling and stratified random sampling) with their estimation procedures and the use of auxiliary information including the Horvitz-Thompson estimator are introduced. Data preparation, non-response and its treatment, variance estimation and analysis of survey data is discussed.

**Lecture notes**
Introduction to the statistical methods of survey research

**Deep Learning: A Probabilistic Approach**

- **W** 2 credits 1G
- **Objective**
  Knowledge of the Elements and the process of a sample survey. Understanding of the paradigm of random samples. Knowledge of simple random sampling and stratified random sampling and capability to apply the corresponding methods. Knowledge of further methods of sampling and estimation as well as data preparation and analysis.

**Spatial Statistics**

- **W** 1 credit 1G
- **Objective**
  The course will provide an overview of the basic concepts and stochastic models that are commonly used to model geostatistical data sets. In addition, the participants will learn a number of geostatistical techniques and acquire some familiarity with software that is useful for analysing spatial data.

**Literature**


**Domain A - Subject-specific Competencies**

- Concepts and Theories assessed
- Techniques and Technologies assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies assessed
- Decision-making not assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management not assessed

**Domain C - Social Competencies**

- Communication not assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility not assessed
- Creative Thinking not assessed
- Critical Thinking not assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed
Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

Abstract
Block course only on prediction problems, aka "supervised learning".

Part 1, Classification: logistic regression, linear/quadratic discriminant analysis, Bayes classifier; additive and tree models; further flexible ("nonparametric") methods.

Part 2, Flexible Prediction: additive models, MARS, Y-Transformation models (ACE, AVAS); Projection Pursuit Regression (PPR), neural nets.

Content
"Data Mining" is a large field from which in this block course, we only treat so called prediction problems, aka "supervised learning".

Part 1, Classification, recalls logistic regression and linear / quadratic discriminant analysis (LDA/QDA) and extends these (in the framework of "Bayes classifier") to (generalized) additive (GAM) and tree models (CART), and further mentions other flexible ("nonparametric") methods.

Part 2, Flexible Prediction (of continuous or "class" response/target) contains additive models, MARS, Y-Transformation models (ACE, AVAS); Projection Pursuit Regression (PPR), neural nets.

Lecture notes
The block course is based on (German language) lecture notes.

Prerequisites / notice
The exercises are done exclusively with the (free, open source) software "R" (http://www.r-project.org). A final exam will also happen at the computers, using R (and your brains!).

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>447-6273-00L</td>
<td>Bayes Methods</td>
<td>W</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Special Students &quot;University of Zurich (UZH)&quot; in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to <a href="mailto:registrar@ethz.ch">registrar@ethz.ch</a>. The Registrar's Office will then register you for the course.</td>
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</table>

Abstract
conditional probability; bayes inference (conjugate distributions, HPD-areas; linear and empirical bayes); determination of the a-posteriori distribution through simulation (MCMC with R2Winbugs); introduction to multilevel/hierarchical models.

Content
Bayes statistics is attractive, because it allows to make decisions under uncertainty where a classical frequentist statistical approach fails. The course provides an introduction into bayesian methods. It is moderately mathematically technical, but demands a flexibility of mind, which should not underestimated.

Literature

Kruschke, J.K., Doing Bayesian Data Analysis, Elsevier2011.

Prerequisites / notice
Prerequisite:Basic knowledge of statistics; Knowledge of R.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>447-6191-00L</td>
<td>Statistical Analysis of Financial Data</td>
<td>W</td>
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<td></td>
<td>Special Students &quot;University of Zurich (UZH)&quot; in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to <a href="mailto:registrar@ethz.ch">registrar@ethz.ch</a>. The Registrar's Office will then register you for the course.</td>
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</table>

Abstract

Objective
Getting to know the typical properties of financial data and appropriate statistical models, incl. the corresponding functions in R.

Diploma Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>447-1990-00L</td>
<td>Diploma Thesis</td>
<td>O</td>
<td>2</td>
<td>4D</td>
<td>Supervisors</td>
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</table>

Abstract
The diploma thesis typically consists of a data analysis of data from a participant's own field of work. The thesis requires a time expenditure of about one or two weeks. Thesis work should prove the participants' capability to apply useful and modern statistical methods to address appropriate questions properly and effectively.

Objective
Thesis work should prove the participants' capability to apply useful and modern statistical methods to address appropriate questions properly and effectively.

DAS in Applied Statistics - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Description</th>
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<tbody>
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<td>W</td>
<td></td>
<td>Eligible for credits</td>
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<tr>
<td>E</td>
<td></td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
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<td>Courses outside the curriculum</td>
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Key for Hours

<table>
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<th>Type</th>
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<td>V</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Key: Special students and auditors need special permission from the lecturers.
In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.
Abstract

Hands-on course on applied aspects of information security. Applied information security, operating system security, OS hardening, computer forensics, web application security, project work, design, implementation, and configuration of security mechanisms, risk analysis, system review.

Objective

The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, logging), application security with an emphasis on web applications (web server setup, common web exploits, authentication, session handling, code security), computer forensics, and risk analysis and risk management.

Content

This course emphasizes applied aspects of Information Security. The students will study a number of topics in a hands-on fashion and carry out experiments in order to better understand the need for secure implementation and configuration of IT systems and to assess the effectivity and impact of security measures. This part is based on a book and virtual machines that include example applications, questions, and answers.

The students will also complete an independent project: based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

Lecture notes


Literature

Recommended reading includes:
* Various: OWASP Guide to Building Secure Web Applications, available online
* O'Reilly, Loukides: Unix Power Tools, O'Reilly & Associates.
* Frisch: Essential System Administration, O'Reilly & Associates.
* NIST: Risk Management Guide for Information Technology Systems, available online as PDF
* BSI: IT-Grundschutzhandbuch, available online

Prerequisites / notice

* The lab allows flexible working since there are only few mandatory meetings during the semester.
* The lab covers a variety of different techniques. Thus, participating students should have a solid foundation in the following areas: information security, operating system administration (especially Unix/Linux), and networking. Students are also expected to have a basic understanding of HTML, PHP, JavaScript, and MySQL because several examples are implemented in these languages.
* Students must be prepared to spend more than three hours per week to complete the lab assignments and the project. This applies particularly to students who do not meet the recommended requirements given above. Successful participants of the course receive 8 credits as compensation for their effort.
* All participants must sign the lab's charter and usage policy during the introduction lecture.

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0463-00L</td>
<td>Security Engineering</td>
<td>W</td>
<td>7 credits</td>
<td>2V+2U+2A</td>
<td>S. Krstic</td>
</tr>
</tbody>
</table>

Abstract

Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.

Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data. The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include
* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class

2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security

3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts

4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience

5. Model-driven security (Part II)
   - Continuation of above topics

6. Security patterns (design and implementation)

7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks

8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis

9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties

10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment

11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience

12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection

13. Guest lecture
    - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
Prerequisite: Class on Information Security

252-1411-00L Security of Wireless Networks W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen
Abstract
Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.

Objective
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

Content

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>268-0201-00L</td>
<td>Information Security Seminar and Project</td>
<td>W 2</td>
<td>S. Matetic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only for CAS and DAS in Cyber Security.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Participants have understood and presented a publication or report on a present topic in information security. By attending other participants presentations students get further introduced to additional current information security related topics/incidents.</td>
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<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>268-0202-00L</td>
<td>Contemporary Topics in Cyber Security</td>
<td>W 3</td>
<td>S. Matetic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only for CAS and DAS in Cyber Security.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course is composed of various sub-modules related to Cyber Security taught by experts on the relevant fields.</td>
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<tr>
<td>Objective</td>
<td>Students are expected to see behind the curtain of current research and engineering activities related to Cyber Security. At the same time students are introduced to contemporary challenges in cyber security by renowned experts.</td>
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</tr>
<tr>
<td>Content</td>
<td>The lectures cover contemporary aspects and challenges in Cyber Security. The goal is to present current fields of research/engineering and the latest results. By way of example, Cyber Security Policy is one of sub-modules presented by researchers of the Center for Security Studies at ETH. Besides faculty members of the computer science department, there will be guest lecturers from industry presenting Cyber Security related challenges in their field of activity.</td>
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</tbody>
</table>

Abstract
Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.

Objective
Participants have understood and presented a publication or report on a present topic in information security. By attending other participants presentations students get further introduced to additional current information security related topics/incidents.

Content
Participants of the seminar are assigned a recent topic in cyber security. They are expected to become acquainted with the assigned issue and to prepare a corresponding presentation in the context of the seminar.

Literature
Will be announced during the course.

DAS in Cyber Security - Key for Type

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

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

ECTS
European Credit Transfer and Accumulation System

W+ Eligible for credits and recommended

Special students and auditors need special permission from the lecturers.
# DAS in Data Science

## Core Courses

### Foundations Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

**Abstract**
Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.

**Objective**
Students master the basic mathematical concepts and algorithms of estimation and machine learning.

**Content**
Review of probability theory;
basics of statistical estimation;
least squares and linear learning;
Hilbert spaces;
Gaussian random variables;
singular-value decomposition;
kernels, methods, neural networks, and more

**Lecture notes**
Lecture notes will be handed out as the course progresses.

**Prerequisites / notice**
solid basics in linear algebra and probability theory

## Capstone Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>266-0100-00L</td>
<td>Capstone Project</td>
<td>O</td>
<td>8</td>
<td>17A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
The capstone project is part of the DAS in Data Science and is an opportunity to apply the knowledge acquired in the program in an independent, real-world project.

**Objective**
To apply the knowledge acquired in the program in an independent, real-world project.

**Content**
The capstone project can be done under the supervision of the Swiss Data Science Center, or any core or adjunct faculty of Data Science.
The project has to be finished within 6 months. Deadline for a project the following semester conducted at the SDSC is mid-June/mid-December.

## Specialisation Track

### Hardware for Machine Learning

*Offered in the Spring Semester.*

<table>
<thead>
<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>227-0155-00L</td>
<td>Machine Learning on Microcontrollers</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Magno, L. Benini</td>
</tr>
</tbody>
</table>

**Abstract**
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

**Objective**
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.

**Content**
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.

**Lecture notes**
Script and exercise sheets. Books will be suggested during the course.

**Prerequisites / notice**
Prerequisites: C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable

## Image Analysis & Computer Vision

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<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>263-5902-00L</td>
<td>Computer Vision</td>
<td>W</td>
<td>8</td>
<td>3V+1U+3A</td>
<td>M. Pollefeys, S. Tang, F. Yu</td>
</tr>
</tbody>
</table>

**Abstract**
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

---

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

The main goal of this lecture is to provide a comprehensive overview into the learning principles of neuronal networks as well as to introduce a diverse skill set (e.g., simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this, the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course, students will be able to:

- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g., digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the mammalian visual cortex. Similar to their neocortical counterparts, ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al., 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g., recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Neural Information Processing

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<th>Number</th>
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<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>227-0421-00L</td>
<td>Deep Learning in Artificial and Biological Neuronal Networks</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>T. Delbrück, B. Grewe</td>
</tr>
</tbody>
</table>

Abstract
Deep Learning (DL) is a brain-inspired weak form of AI that allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

Objective
The main goal of this lecture is to provide a comprehensive overview into the learning principles of neuronal networks as well as to introduce a diverse skill set (e.g., simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this, the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course, students will be able to:

- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g., digit classification) tasks in a supervised manner.

Neuromorphic Engineering I

Registration in this class requires permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:
Enrollment to this course is only possible at ETH. No enrollment to module INI404 at UZH.
Please mind the ETH enrollment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogously to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

Statistics

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
</tbody>
</table>

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

Content
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

Literature

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

<table>
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<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
</tbody>
</table>

Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

Prerequisites / notice
The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

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</tr>
</thead>
<tbody>
<tr>
<td>401-3612-00L</td>
<td>Stochastic Simulation</td>
<td>W</td>
<td>5 credits</td>
<td>3G</td>
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</tbody>
</table>

Abstract
This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

Objective

Content
Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on Time Series Analysis.

### Prerequisites / notice
Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

#### 401-3621-00L Fundamentals of Mathematical Statistics

**Abstract**
The course covers the basics of inferential statistics.

**Objective**
Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

**Content**
- Stationarity
- Autocorrelation
- Trend estimation
- Simulation of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

**Literature**

**Prerequisites / notice**
Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

#### 401-3622-00L Statistical Modelling

**Abstract**
In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.

**Objective**
Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

**Content**

**Prerequisites / notice**
Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

#### 401-3628-14L Bayesian Statistics

**Abstract**
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

**Objective**
Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

**Content**
- Topics that we will discuss are:
  - Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffrey's prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

**Prerequisites / notice**
Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

#### 401-4623-00L Time Series Analysis

**Abstract**
The course offers an introduction into analyzing time series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

**Objective**
The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

**Content**
- This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.
  - The key topics which will be covered as:
    - Stationarity
    - Autocorrelation
    - Trend estimation
    - Elimination of seasonality
    - Spectral analysis, spectral densities
    - Forecasting
    - ARMA, ARIMA, Introduction into GARCH models

**Literature**
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

**Prerequisites / notice**
Basic knowledge in probability and statistics.
Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course introduces advanced concepts and algorithms for supervised and unsupervised learning, reinforcing the statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
- No lecture notes, but slides will be made available on the course webpage.

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research papers.


Additional papers will be available via the course Moodle.

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least “Introduction to Machine Learning” or an equivalent course offered by another institution. PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.

To facilitate deeper understanding, an important part of the course will be a group hands-on programming project where students will build a system based on the learned material.
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

* Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
* Defenses against attacks
* Combining gradient-based optimization with logic for encoding background knowledge
* Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
* Probabilistic certification of deep neural networks
* Training deep neural networks to be provably robust via automated reasoning
* Fairness (different notions of fairness, certifiably fair representation learning)
* Federated Learning (introduction, security considerations)

Prerequisites / notice

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

For solving assignments, some programming experience in Python is expected.

263-3210-00L  Deep Learning  W  8 credits  3V+2U+2A  F. Perez Cruz, A. Lucchi

Abstract

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab http://da.inf.ethz.ch/teaching/2019/CIL/
  - Statistical Learning Theory http://ml2.inf.ethz.ch/courses/slt/
  - Probabilistic Artificial Intelligence https://las.inf.ethz.ch/teaching/pai-f18

263-5210-00L  Probabilistic Artificial Intelligence  W  8 credits  3V+2U+2A  A. Krause

Abstract

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit “intelligent” behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content

Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice

Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

Big Data Systems

Number  Title  Type  ECTS  Hours  Lecturers
252-0834-00L  Information Systems for Engineers  W  4 credits  2V+1U  G. Fourny

Abstract

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

263-2800-00L Design of Parallel and High-Performance Computing

Number of participants limited to 125.

Objective

Advanced topics in parallel and high-performance computing.
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice

This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-3010-00L Big Data

The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.
Objective

This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Literature

Large scale analytics and machine learning are outside of the scope of this course. Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
  - "Information Systems for Engineers" (SQL, relational databases): this Fall
  - "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

<table>
<thead>
<tr>
<th>DAS in Data Science - Key for Type</th>
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<tbody>
<tr>
<td><strong>O</strong> Compulsory</td>
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<td><strong>W</strong> Eligible for credits and recommended</td>
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<th>Key for Hours</th>
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<tr>
<td><strong>V</strong> lecture</td>
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<td><strong>G</strong> lecture with exercise</td>
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<td><strong>U</strong> exercise</td>
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<td><strong>S</strong> seminar</td>
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<td><strong>K</strong> colloquium</td>
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<td><strong>P</strong> practical/laboratory course</td>
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<td><strong>A</strong> independent project</td>
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<td><strong>D</strong> diploma thesis</td>
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<td><strong>R</strong> revision course / private study</td>
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<th>ECTS</th>
<th>European Credit Transfer and Accumulation System</th>
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<td></td>
<td><strong>Special students and auditors need special permission from the lecturers.</strong></td>
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**Diploma Project**

**Course offer from the Master Program in Electrical Engineering and Information Technology**

### Diploma Project

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
227-1101-00L | How to Write Scientific Texts | E- | 0 credits | | U. Koch

**Abstract**
The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training.

**Objective**
Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

**Content**
* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the "in this paper" paragraph, the scientific part, the summary, Equations, Figures).

* Topic 2: Power Point Presentations.

* Topic 3: Citation Rules and Citation Software.

* Topic 4: Guidelines for Research Integrity.

**Literature**
ETH "Citation Etiquette", see www.plagiate.ethz.ch.


**Prerequisites / notice**
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

### Diploma Thesis

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
227-3001-00L | Diploma Thesis | O | 12 credits | 36D | Professors

**Abstract**
The Diploma of Advanced Studies finishes with a 3-months diploma thesis which is directed by a professor of the department ITET. Students prove their ability to conduct independent scientific research on a specific research problem, using skills and knowledge acquired during the program. The thesis includes a written report and an oral presentation.

**Objective**
see above

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**DAS in Information Technology and Electrical Engineering - Key for Type**

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<tbody>
<tr>
<td>Eligible for credits</td>
<td>Recommended, not eligible for credits</td>
<td>Courses outside the curriculum</td>
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<td>Dr</td>
<td>O</td>
<td>W+</td>
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<tr>
<td>Suitable for doctorate</td>
<td>Compulsory</td>
<td>Eligible for credits and recommended</td>
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**Key for Hours**

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<td>lecture</td>
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<td>practical/laboratory course</td>
<td>independent project</td>
<td>diploma thesis</td>
<td>revision course / private study</td>
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</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The DAS in Military Sciences programme is executed every second year.

Next start in Autumn Semester 2021.

Courses Offered

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>853-0063-02L</td>
<td>Military History I (without Exercises)</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Wettstein, T. Cubito, M. Olsansky</td>
</tr>
</tbody>
</table>

**Abstract**
The purpose of the lecture is to outline the development of the armed forces (assets regarding manpower, technology and armament), the concepts of warfare and the actual warfare in the 19th and 20th century.

**Objective**
- Distinguish between military history as a subject and historiography as a way of describing events;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).

**Content**
The lecture first examines the bases of the science of (military) history. It focuses on how military history developed from war history, on specific similarities and differences between military history and general historiography, the different ways of dealing with history in Switzerland, Germany, France and in the Anglo-Saxon cultural area (different approaches) as well as on institutions which deal with military history such as universities, military academies, national and international commissions and associations etc.

The lecture is structured along the lines of the concept of "Military Revolution" and starts with the formation of modern, European armed forces after the Oranian Army reform in the 17th century. Based on the "Military Revolution" approach, the lecture examines the structural changes regarding the armed forces and the development of warfare from the 18th to the 20th century. Special emphasis will be put on how the battlefield was revolutionized due to the Napoleonic wars, the industrialization in the 19th century, the First World War, the mechanization and totalization during the Second World War and the period of the Cold War.

**Literature**

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>853-0047-00L</td>
<td>World Politics Since 1945: The History of International Relations Only for Public Policy BA and DAS Military Sciences</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. Dossi, L. Horovitz</td>
</tr>
</tbody>
</table>

**Abstract**
This lecture series provides students with an overview of the development of international relations since the end of World War II. The first part of the series deals with the development of and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

**Objective**
- By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of the Second World War.

**Content**
- cf. "Diploma Supplement"

**Prerequisites / notice**
The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver Roos (oliver.roos@sipo.gess.ethz.ch)

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<tbody>
<tr>
<td>853-0082-00L</td>
<td>Strategic Studies I</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Mantovani</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture series treats high-impact strategic theory from antiquity to the present.

**Objective**
- The participants know how the understanding of strategy has evolved over time.
- They understand the interplay of strategy's basic components: ends, ways, means.
- They know the most important classics of strategy and war theory, especially against their specific historical background.
- Based on the analysis of historical and contemporary examples, they are aware of the mismatch between declaration and implementation of any given strategy.
- They are capable of analyzing original texts and modern scholarly works in the field of strategic studies.

**Content**
The two-term lecture series treats classic texts of strategic studies from antiquity to the present. Term 1 covers the theories up until roughly 1900, term 2 treats the theories ever since.

**Literature**

**Prerequisites / notice**
- The lecture is held in German.
- Passive knowledge of English and French are required.

**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories - assessed
- Domain B - Method-specific Competencies: Analytical Competencies - assessed; Problem-solving - assessed
- Domain D - Personal Competencies: Creative Thinking - assessed; Critical Thinking - assessed

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<tbody>
<tr>
<td>853-0037-01L</td>
<td>Military Psychology and Pedagogy I (Without Exercises)</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>H. Annen</td>
</tr>
</tbody>
</table>

**Abstract**
Examine the fundamentals of the two sciences and establish links with military life. Discuss various schools of thought in psychology and focus on content and process theories of motivation. Explore characteristics of pedagogical thinking and discuss the values of military education with reference to the young adult serving in the armed forces.

**Objective**
- Becoming acquainted with basic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences

Overall, the objective is to become acquainted with the basics of both scientific areas and to make references to military practice. Military psychology is a branch of applied psychology; consequently selected aspects of psychological principles will be covered. Military pedagogy hasn’t yet established itself firmly as an independent scientific discipline, it nevertheless can draw on a deep-seated tradition in Switzerland. Thus, the great importance that has been attached to the discussion of education in Swiss society and academia will be taken into account. Subjects:
- History of military psychology
- Psychological images of humanity (psychoanalysis, behaviourism, behavioural biology, humanistic psychology, cognitivism)
- Motivational theories
- Defence-, service-, operational- and combat motivation
- Swiss military pedagogy
- Education as defining feature of pedagogic thinking and acting

The lecture is supported by a virtual learning environment containing relevant documents (presentations and texts) and information to further literature.

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

**Domain C - Social Competencies**
- Leadership and Responsibility
- Self-presentation and Social Influence

**Domain D - Personal Competencies**
- Critical Thinking
- Self-awareness and Self-reflection

### Literature

- Annen, H., Steiger, R. & Zwygart, U.: Gemeinsam zum Ziel, Huber, Frauenfeld 2004 (provided as pdf)
- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

**Domain C - Social Competencies**
- Leadership and Responsibility
- Self-presentation and Social Influence

**Domain D - Personal Competencies**
- Critical Thinking
- Self-awareness and Self-reflection

### Literature

- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)
- Swiss military pedagogy
- Motivational theories
- Psychological images of humanity (psychoanalysis, behaviourism, behavioural biology, humanistic psychology, cognitivism)
- Subjects:

### Objective

The aim of this lecture is to give students an introductory overview of relevant topics regarding leadership research and practice, thus enabling them to gain a deeper understanding of the leadership phenomenon. Students should understand different concepts of leadership and the complex interaction between individuals, groups, organisation, context and situation. They should be informed about the evolution of the understanding of mankind in relation to working processes and its impact on organizations and the understanding of leadership theory in the past 100 years. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations. They should recognize the fundamental importance of communication in leadership situations and receive input which enables them to communicate adequately in specific situations.

### Literature

- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)
- Swiss military pedagogy
- Motivational theories
- Psychological images of humanity (psychoanalysis, behaviourism, behavioural biology, humanistic psychology, cognitivism)
- Subjects:

### Objective

The lectures “Leadership I” (WS) and “Leadership II” (SS) have been designed as a two-semester lecture series, but may also be followed independently of one another or in reverse order. “Leadership I” covers the following fields: leadership basics, leadership theories and leadership styles, the concept of leadership responsibility and the role of communication in practical leadership.

### Literature

- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)
- Swiss military pedagogy
- Motivational theories
- Psychological images of humanity (psychoanalysis, behaviourism, behavioural biology, humanistic psychology, cognitivism)
- Subjects:

### Objective

The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures). Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.
We start with an overview of cybersecurity issue from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulatory contexts).

Lecture notes
A script with background information and comments on the literature will be made available at the beginning of the semester.

Literature
Literature for each session will be available on Moodle.

Prerequisites / notice
The lecture is being supported by a website on Moodle.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | not assessed |
| | Media and Digital Technologies | not assessed |
| | Problem-solving | assessed |
| Domain C - Social Competencies | Communication | not assessed |
| | Cooperation and Teamwork | not assessed |
| | Sensitivity to Diversity | not assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Self-direction and Self-management | not assessed |

853-8002-00L The Role of Technology in National and International Security Policy

Abstract
The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective
Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content

Literature
Literatur für die einzelnen Sitzungen wird auf Moodle bereitgestellt. The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver Roos, oliver.roos@sipo.gess.ethz.ch.

853-0101-02L Defense Economics I

Abstract
In terms of structure and content, the event follows the lecturer's book "Militärökonomie" (Military Economics), which is available in two language versions:
- German language: ISBN 978-3-658-06146-3

Objective
* Recognizing parallels and contrasts between business and military thinking;
* Recognize and analyze planned economic systems;
* Understand the link between institutions, human action and economic results.

Content
The semester program of the course is divided into 14 modules of 90 minutes each, which combine lecture (teaching of analytical techniques) and exercise (application by means of concrete case studies).

The contents correspond to sections 1 to 2.2.5 of the above book. The following will be discussed:
1. fundamental military economic problems including historical introduction to the topic
2. the institutional foundations of a military organisation
3. the modern military as a planned economy system
4. actors and stakeholders in the system

Lecture notes
Lecture slides are given to the participants before the first lecture. In addition, the above mentioned book will be handed over to the participants. Participants of the lecture who are not professional officer candidates are requested to obtain the book from the library or bookstore.

Literature

Prerequisites / notice
none.

DAS in Military Sciences - Key for Type

<p>| Dr | Suitable for doctorate | W | Eligible for credits |
| E- | Recommended, not eligible for credits | W+ | Eligible for credits and recommended |
| O | Compulsory | Z | Courses outside the curriculum |</p>
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS: European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Lectures

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>115-0500-00L</td>
<td>Preliminary Course: Introduction to Swiss Spatial Planning</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>D. Jerjen, A. Schneider</td>
</tr>
<tr>
<td></td>
<td><em>Only for MAS, DAS and CAS in Spatial Planning</em></td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Tasks of spatial planning; objectives and principles; instruments of spatial planning; federal planning; cantonal structural planning; constructing outside of building zones; communal planning; land use planning; compensation of benefits released by planning; environmental protection and spatial planning; energy and spatial planning; densification with quality; case studies and exercises.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The preliminary course introduces students to the fundamentals of formal spatial planning in Switzerland. It gives a first overview over background and context of spatial planning as well as instruments of spatial planning.</td>
</tr>
<tr>
<td>115-0502-00L</td>
<td>Lecture Week 02: Urban Planning and Urban Design I</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>S. Kretz, C. Salewski</td>
</tr>
<tr>
<td></td>
<td><em>Only for MAS, DAS and CAS in Spatial Planning</em></td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Contemporary urbanization phenomena and urban design methods and tools. Lectures are accompanied by urban design exercises.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Introduction to current challenges and methods in urban design, to theories of urban planning and to exemplary urban design projects.</td>
</tr>
<tr>
<td>115-0503-00L</td>
<td>Lecture Week 03: Landscape Architecture</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>G. Vogt</td>
</tr>
<tr>
<td></td>
<td><em>Only for MAS, DAS and CAS in Spatial Planning</em></td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>Methods, tools and processes in large scale landscape architectural design. On the basis of a case study, «Basel!», we shall discuss these themes in lectures and practical exercises. The design-led approach will be extended with a series of talks that will establish a theoretical grounding in current issues of landscape- and urban design.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>On the basis of theoretical foundations the one-week teaching block explains the possibi-lies and methods of design at different stages of the process. The students will become sensitive to current and future issues and approaches of landscape on a large scale, with the aim that they will engage with critical debate on the topic and take their own position.</td>
</tr>
<tr>
<td>115-0504-00L</td>
<td>Lecture Week 04: Landscape and Environmental Planning</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>A. Grét-Regamey, U. Wissen Hayek</td>
</tr>
<tr>
<td></td>
<td><em>Only for MAS, DAS and CAS in Spatial Planning</em></td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>Discussion of the proposition of sustainability in landscape and environmental planning; comprehending landscape development with a system dynamics approach; planning of landscape development across cantonal and communal boundaries; negotiating various stakeholder interests based on the example of current practical cases; instruments and approaches for sustainable landscape development.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Overview of tasks of landscape and environmental planning as well as essential theories; insights in planning approaches and application of new instruments related to current problems for a sustainable landscape development.</td>
</tr>
<tr>
<td>115-0501-00L</td>
<td>Lecture Week 01: Spatial Planning: Tasks and Methods</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>M. Nollert</td>
</tr>
<tr>
<td></td>
<td><em>Only for MAS, DAS and CAS in Spatial Planning</em></td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>Current and future significant tasks of Spatial Planning in Switzerland. In addition to the existing inner development of settlements, the importance of new challenges such as climate adaptation and the implementation of the mobility turn is rising. What they have in common is the need of methods and instruments for exploring, clarifying and solving complex tasks.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
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<td></td>
<td>The aim of the course is the acquaintance and the comprehension of tasks, methods and instruments of spatial planning in Switzerland and to discuss them in the light of future challenges. In particular, the methodological modules of the course form an essential basis for working on the two study projects of the MAS programme.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
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<td></td>
<td>The tasks are contrasted with a brief overview of existing spatial planning instruments in Switzerland. On the one hand, the aim is to develop a common understanding of the formal and informal procedures and instruments of spatial planning; on the other hand, these are also to be discussed with regard to their effectiveness for current and future challenges.</td>
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<tr>
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<td>At the centre of the teaching unit is the teaching and methodological basis for exploring, clarifying and solving complex issues. These refer to the questions and pitfalls of perceiving and dealing with complexity, to methodological elements of processes for clarifying difficult spatially significant tasks with a large number of actors involved, as well as methods of situation assessment, design and decision-making as a basis for developing solutions.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>A reader with central elements of the course and background information will be provided</td>
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<tr>
<td></td>
<td>Taught competencies</td>
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<tr>
<td></td>
<td>Domain A - Subject-specific Competencies</td>
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<tr>
<td></td>
<td>Concepts and Theories</td>
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<td></td>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td></td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
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<tr>
<td></td>
<td>Analytical Competencies</td>
<td></td>
<td></td>
<td></td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
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<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Domain C - Social Competencies</td>
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<tr>
<td></td>
<td>Communication</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Negotiation</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td></td>
<td></td>
<td></td>
<td>not assessed</td>
</tr>
</tbody>
</table>

### DAS in Spatial Planning - Key for Type

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

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<table>
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<tr>
<th>Key for Hours</th>
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<tbody>
<tr>
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<tr>
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<td>D</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
DAS in Transport Engineering

Starts every second Autumn Semester.

Next start: HS21
Duration: Two years.

► Compulsory Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>149-0002-00L</td>
<td>Traffic Engineering Only for CAS/DAS in Transport Engineering and MAS in Future Transport Systems</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Fellendorf</td>
</tr>
</tbody>
</table>

► Elective Modules

Elective modules start from Autumn Semester HS 2022 and Spring Semester FS 2023 on.

► Diploma Thesis

Start of diploma thesis from Autumn Semester 2022 on.

DAS in Transport Engineering - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
</tbody>
</table>

| W+   | Eligible for credits and recommended            |
| Z    | Courses outside the curriculum                  |
| Dr   | Suitable for doctorate                          |

Key for Hours

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<td>R</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## DAS Preparation for the Swiss Federal Examination in Pharmacy

### First Series of Courses (Group A)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0521-00L</td>
<td>Pharmacology and Toxicology I</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>U. Quitterer, J. Abd Alla</td>
</tr>
</tbody>
</table>

#### Abstract
The two-semester lecture course will provide a detailed understanding of the fundamentals of drug action and the mechanisms of action and therapeutic use of the important classes of drugs. The lectures are intended for students of pharmaceutical sciences.

#### Objective
The lectures will provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects.

#### Content
Topics include disease-relevant macroscopic, microscopic, pathobiochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicology, contraindications and dosage of relevant drug classes. Basic principles of clinical pharmacology and pharmacotherapy will be covered.

#### Lecture notes
A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.

#### Literature
- **Recommended reading:**

#### Prerequisites / notice
Voraussetzungen: Abschluss Grundstudium

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0581-00L</td>
<td>Gene Technology</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>K. Eyer, J. Scheuermann</td>
</tr>
</tbody>
</table>

#### Abstract
The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology.

#### Objective
The course gives an overview of current state-of-the art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.

#### Content
**I) Genomics and transcriptomics**
- Methods and Techniques:
  - Recombinant DNA technology
  - Next generation sequencing methods, sequencing of genomes
  - CRISPR technology
- Application to human biology:
  - Functional genomics/transcriptomics
  - Principles of cancer, genetic diseases
  - Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

**II) Proteomics**
- Methods and Techniques:
  - Protein cloning and expression
  - The antibody molecule
  - Measurement and determination of biomolecular interactions
  - Protein characterization and engineering
  - Modifications and radioactive labelling
- Application to human biology:
  - Protein therapeutics
  - Proteomic approaches for identification of novel disease-related targets and biomarkers

**III) Drug discovery: Protein-based libraries**
- Immune repertoire mining
- Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

#### Lecture notes
The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

#### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Decision-making</td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0830-00L</td>
<td>Pharmaceutical Immunology</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>C. Halin Winter, V. Collado Diaz</td>
</tr>
</tbody>
</table>

#### Abstract
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

#### Objective
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.
Content
Chapters 1 - 11 of the Janeway's ImmunoBiology, by Kenneth Murphy (9th Edition; Garland).

Literature
Janeway's ImmunoBiology, by Kenneth Murphy (9th Edition).

Paperback
[www.garlandscience.com]

535-0421-00L Galenical Pharmacy I

O 2 credits 2G J.-C. Leroux, E. Giger

Abstract
Principles and technologies for the manufacturing of dosage forms and drug delivery systems. Knowledge of pharm. excipients, materials, containers, liquid and semi-solid dosage forms, their production, function, quality and application. Comprehension of molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dosage forms.

Objective
Knowledge of the most important pharmaceutical excipients, materials, containers, liquid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dispense dosage forms.

Content
Introduction and overview of important fundamentals, principles and technologies for the development and manufacturing of dosage forms and drug delivery systems. Overview of the most important pharmaceutical excipients and polymers, their structure, properties and processing; importance of materials properties for containers. Pharmaceutical solvents, fundamentals of solubility and solubilization of drugs. Water treatment processes, sterilization techniques and quality requirements of pharmaceutical water. Parenteral dosage forms and liquid ophthalmics. Surfactants, micelle formation and colloidal systems. Liquid suspensions and emulsions. Stabilization measures in dosage forms.

Literature

Prerequisites / notice
Language: German and English

Galenical Pharmacy I
O 2 credits 2G J.-C. Leroux, E. Giger

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking not assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

535-0525-00L Pharmaceutical Cases

O 1 credit 1G D. Stämplfi, S. Erni, E. Kut Bacs, P. Obrist

Abstract
The course places the basic pharmaceutical knowledge acquired so far in an applied therapeutic context and fosters interdisciplinary thinking in pharmaceutical sciences. Common pharmaceutical case studies, as they can occur in the professional everyday life of a pharmacist, are worked out in group works, presented and discussed.

Objective
Students

• Are able to analyse, present and discuss common case studies from the pharmacist's practice, based on their basic knowledge in pharmacology.
• deepen their knowledge of therapeutic substance classes and therapy guidelines.
• are able to analyse the pharmacological profiles of selected drugs in a therapeutic context (e.g. with regard to undesirable other effects and interactions).
• are able to compare different drugs and derive their therapy-relevant characteristics.

Content
Pharmaceutical case studies from different therapeutic fields comprehend following subject areas:

- Indication
- Adverse effects
- Interactions
- Contraindications

Lecture notes
Is made available via Moodle.

Literature
As stated in the cases.

Prerequisites / notice
The lecture Pharmacology and Toxicology I (535-0521-00L) must be attended in parallel to or prior to this course.

The course takes place weekly from 5.11.19-17.12.19. The case studies are worked on in groups of 2-3 students, submitted by e-mail, presented by one group and discussed in the plenum.
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

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

Domain D - Personal Competencies
- Critical Thinking
- Self-direction and Self-management

Concepts and Theories
not assessed

Techniques and Technologies
not assessed

Analytical Competencies
assessed

Decision-making
not assessed

Media and Digital Technologies
not assessed

Problem-solving
not assessed

Communication
assessed

Cooperation and Teamwork
assessed

Self-presentation and Social Influence
not assessed

Critical Thinking
assessed

Self-direction and Self-management
assessed

Domain A - Subject-specific Competencies

Concepts and Theories
not assessed

Domain B - Method-specific Competencies

Analytical Competencies
assessed

Decision-making
not assessed

Media and Digital Technologies
not assessed

Problem-solving
not assessed

Domain C - Social Competencies

Communication
assessed

Cooperation and Teamwork
assessed

Self-presentation and Social Influence
not assessed

Domain D - Personal Competencies

Critical Thinking
assessed

Self-direction and Self-management
assessed

Second Series of Courses (Group A)

Compulsary Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-5512-00L</td>
<td>Triage, Diagnostics, Therapy Support</td>
<td>O</td>
<td>9</td>
<td>12G</td>
<td>E. Kut Bacs, S. Emi, P. Obrist, D. Petralli-Nietlisbach, K. Prader-Schneiter, I. S. Vogel Kahmann, P. Wiedemeier</td>
</tr>
</tbody>
</table>

Abstract
This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

Objective
Students

\begin{itemize}
  \item know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below.
  \item can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
  \item know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).
\end{itemize}

Content
"Pharmaceutical Care" und "Health Care";

- Häufigste Erkrankungen und Therapien der
- Allergologie
- Angiologie und Hämatologie
- Dermatologie
- Endokrinologie und Diabetologie
- Gastroenterologie
- Infektiologie
- Kardiologie
- Neurolgie
- Ophthalmologie
- Otorhinolaryngologie
- Pneumologie
- Psychiatrie
- Rheumatologie
- Urologie

Lecture notes
Provided via myStudies.

Literature
As stated in the lecture notes.

Prerequisites / notice

Please note that the assessment of this course must be passed (not compensable).

The performance assessment of the course takes place in two written online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

Pharmacology and Toxicology III must be visited at the same time.

Compulsary Courses II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0030-00L</td>
<td>Therapeutic Proteins</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>C. Halin Winter, D. Neri</td>
</tr>
</tbody>
</table>

Abstract
In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.

Objective
Students know and understand:
- basic mechanisms and regulation of the immune response
- the pathogenic mechanisms of the most important immune-mediated disorders
- the most frequently used expression systems for the production of therapeutic proteins
- the use of protein engineering tools for modifying different features of therapeutic proteins
- the mechanism of action of selected therapeutic proteins and their application
- basic concepts in the GMP production of therapeutic proteins
The course is divided into two parts. The first part provides a detailed understanding of drugs and pharmacotherapy of infectious diseases and cancer. The second part gives an overview of the field of pharmacogenomics with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Objective
The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases and cancer. The course also provides an overview of the field of pharmacogenomics, with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Content
Topics include the pharmacology and pharmacotherapy of infectious diseases and cancer. In the field of pharmacogenomics, the course is focused on genetics, genome-wide association studies, genetic disease predisposition, examples of genetic variability of drug metabolism and drug responses, identification of new drug targets, relevance of pharmacogenomics for clinical drug development, and toxicogenomics.

Lecture notes
A script is provided for each lecture course. The scripts define important and exam-relevant contents of lectures. Scripts do not replace the lecture.

Literature
Recommended reading:
- The classic textbook in Pharmacology:
- Goodman and Gilman’s The Pharmacological Basis of Therapeutics
- ISBN-10: 1259584739

or

- Klaus Aktories, Ulrich Förstermann, Franz Hofmann, Klaus Starke
- Allgemeine und spezielle Pharmakologie und Toxikologie
- 12th edition (2017)
- Urban & Fischer (Elsevier, München)

535-0041-00L
Pharmacology and Toxicology III
W
2 credits
2G
M. Detmar, U. Quitterer

Abstract
The course is divided into two parts. The first part provides a detailed understanding of drugs and pharmacotherapy of infectious diseases and cancer. The second part gives an overview of the field of pharmacogenomics with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Objective
The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases and cancer. The course also provides an overview of the field of pharmacogenomics, with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Content
Topics include the pharmacology and pharmacotherapy of infectious diseases and cancer. In the field of pharmacogenomics, the course is focused on genetics, genome-wide association studies, genetic disease predisposition, examples of genetic variability of drug metabolism and drug responses, identification of new drug targets, relevance of pharmacogenomics for clinical drug development, and toxicogenomics.

Lecture notes
A script is provided for each lecture course. The scripts define important and exam-relevant contents of lectures. Scripts do not replace the lecture.

Literature
Recommended reading:
- The classic textbook in Pharmacology:
- Goodman and Gilman’s The Pharmacological Basis of Therapeutics
- ISBN-10: 1259584739

or

- Klaus Aktories, Ulrich Förstermann, Franz Hofmann, Klaus Starke
- Allgemeine und spezielle Pharmakologie und Toxikologie
- 12th edition (2017)
- Urban & Fischer (Elsevier, München)

535-0050-00L
Pharmacoepidemiology and Drug Safety
W
3 credits
2G
A. Burden, S. Russmann

Abstract
Introduction to the principles, methods and applications of pharmacoepidemiology and drug safety. Drug safety in the pharmaceutical industry and regulatory authorities, but also for hospital and office pharmacists. Another focus is the evaluation and interpretation of pharmacoepidemiological drug safety studies in the medical literature and the evaluation of benefits vs. risks.

Objective
Objectives:
- To familiarize participants with the principle methods and applications of pharmacoepidemiology and drug safety that is relevant for industry, regulatory affairs, but also for clinical pharmacists in hospitals and office pharmacies.
- To perform independently a causality assessment of suspected adverse drug reactions in patients.
- To study designs and biostatistics used for the quantitative evaluation of drug safety.
- To set up programs that can effectively reduce medication errors and improve drug safety in clinical practice, particularly in hospitals.

Content
- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarketing clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, ‘Big Data’
- Interactive discussion of many real-life examples for each topic

Lecture notes
This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups. Reading material and scripts will be provided for each week.

Literature
Recommended literature:
- Rothman: Introduction to Epidemiology
- Strom, Kimmel, Hennessy: Textbook of Pharmacoepidemiology
- Gigerenzer: Risk Savvy - How to Make Good Decisions

535-0137-00L
Clinical Chemistry II
W
1 credit
1V
M. Hersberger

Abstract
Detailed knowledge on particular aspects of clinical chemistry and medical laboratory diagnostics concerning quality control, point-of-care analytics, analytics of kidney stones, tumor markers, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Objective
Detailed knowledge on the implementation and interpretation of clinical laboratory diagnostic tests. Competence to interpret selected tests.

Content
Internal and external quality control, point-of-care analytics, analytics of kidney stones, use of tumor marker determinations, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Lecture notes
Documentation will be available before the lectures electronically.

Literature
- Jürgen Haltbruch, Klinische Chemie und Hämatologie für den Einstieg, Thieme Verlag
- Harald Renz, Praktische Labordiagnostik, de Gruyter Verlag
- Walter Guder, Das Laborbuch für Klinik und Praxis, Elsevier Verlag
- Lothar Thomas, Labor und Diagnostik, TH Books
- William Marshall, Clinical Chemistry, Mosby Ltd.
- Alan H.B. Wu, Tietz, Clinical Guide to Laboratory Tests, Saunders
Second Series of Courses (Group B)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

Objective
Students
- know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below.
- can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).

Content
"Pharmaceutical Care" und "Health Care":
- Häufigste Erkrankungen und Therapien der
  - Allergologie
  - Angiologie und Hämatologie
  - Dermatologie
  - Endokrinologie und Diabetologie
  - Gastroenterologie
  - Infektiologie
  - Kardiologie
  - Neurologie
  - Ophthalmologie
  - Otorhinolaryngologie
  - Pneumologie
  - Psychiatrie
  - Rheumatologie
  - Urologie
Grundlagen der Chiropraktischen Medizin und Physiotherapie.

Prerequisites / notice

Please note that the assessment of this course must be passed (not compensable).

The performance assessment of the course takes place in two written online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

Pharmacology and Toxicology III must be visited at the same time.

Practical Pharmacy I and Compensatory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0137-00L</td>
<td>Clinical Chemistry II</td>
<td>O</td>
<td>1 credit</td>
<td>1V</td>
<td>M. Hersberger</td>
</tr>
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</table>

Abstract
Detailed knowledge on particular aspects of clinical chemistry and medical laboratory diagnostics concerning quality control, point-of-care analytics, analytics of kidney stones, tumor markers, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Objective
Detailed knowledge on the implementation and interpretation of clinical laboratory diagnostic tests. Competence to interprete selected tests.

Content
Internal and external quality control, point-of-care analytics, analytics of kidney stones, use of tumor marker determinations, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

Prerequisites / notice

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

Pharmacology and Toxicology III must be visited at the same time.
As specified in the lecture notes
Organisation of institutional environments (emergency hospitals), with special focus on the medication process and institutional

Einblick in die allgemeine praktische Medizin mit ihren verschiedenen Schnittstellen und den Entscheidungsgrundlagen. Klinische

Hours
This course provides basic clinical and pharmaceutical knowledge and its application for triage, diagnostics and therapy support for the

• Students understand the concept of continuum of care and its practical implementation. They know the medication process within an

3G
Provided via myStudies.

• The students are able to produce pharmaceutical relevant drug Systems without further assistance, lege artis, applying the right techniques

2 credits
Pharmaceutical Manufacturing in Small Quantities
students
Pharmaceutical Manufacturing relevant for the community pharmacy considering the “GMP-Regeln in kleinen Mengen” of the

3 credits
Clinical Trainings •
Basic training on and around patients with practical confrontation. The path of acute patients from patient presentation, through triage and
diagnostics to therapy.

535-5522-00L
Therapeutic Skills II

for detailed learning objectives, see the guideline

Content

• complementary medicine
• phytotherapy
• wound care
• pharmaceutical care 2
• nephrology

Abstract
This course provides basic clinical and pharmaceutical knowledge and its application for triage, diagnostics and therapy support for the

Objective

- know and understand the pathomechanisms and the clinical lead and warning symptoms (red flags) of the most common diseases in the

Prerequisites / notice
Safety conceptt: https://chab.ethz.ch/studium/bachelor1.html

Content

• geriatrics
• gynaecology
• oncology
• paediatrics
• neurology (epilepsy)
• nutrition

Lecture notes
Provided via myStudies.

Literature
As specified in the lecture notes

Practical Pharmacy II

Number
535-5524-00L
Clinical Trainings •

Type
ECTS
Hours
Lecturers

O
3 credits
3G

535-5522-00L
Therapeutic Skills II •

O
3 credits
3G

535-5502-00L
Pharmaceutical Manufacturing in Small Quantities (Compounding) •

O
3 credits
5G
P. G. Tiefenböck, A. Romagna

535-5503-00L
Institutional Pharmacy •

O
2 credits
3G
P. Wiedemeier, J. Beney, M. Lutters, I. S. Vogel Kahmann

Abstract

Pharmaceutical Manufacturing relevant for the community pharmacy considering the “GMP-Regeln in kleinen Mengen” of the Pharmacopoeia: The preparation of extemporaneous products covering the most common forms under consideration of their Risks and Quality Assurance.

Objective


Content

Einblick in die allgemeine praktische Medizin mit ihren verschiedenen Schnittstellen und den Entscheidungsgrundlagen. Klinische

Pharmacopoeia: The preparation of extemporaneous products covering the most common forms under consideration of their Risks and Quality Assurance.

Objective

The students are able to produce pharmaceutical relevant drug Systems without further assistance, lege artis, applying the right techniques and material. The production and packaging has to follow GMP rules and tailored for the patients need. The quality control and correct documentation have to be followed. The students know the most relevant specifications, concentration and dosing ranges of common APIs and excipients. The students are familiar with the relevant literature (Pharmaceutical and legal basis) regarding the Pharmaceutical manufacturing relevant for the community pharmacies

Content

Vermittlung der wichtigsten Kenntnisse, Arbeitsschritte und -techniken im Bereich der Arzneimittelherstellung in kleinen Mengen (Formula) mit Fokus auf der Herstellung, Qualitätssicherung und Risikobeurteilung einschliesslich der patientenspezifischen Abgabepraxis.

In den Praktika: Anhand praxis-relevanter Beispiele wird die Aufgabenplanung, die Fertigung einschliesslich die korrekte Verwendung der Gerätschaften, die Inprozesskontrolle, die Verpackung und die Qualitätssicherung diverser Rezepte und Arzneiformen geübt. Unter Einbezug risikoadaptierter Massnahmen erfolgt die Qualitätssicherung, -kontrolle und Einhaltung von Hygienerichtlinien gemäss den geltenden Arzneibüchern. Die Studierenden vertiefen damit ihre GMP-relevanten Kenntnisse und Fertigkeiten

Prerequisites / notice
Safety conceptt: https://chab.ethz.ch/studium/bachelor1.html

Abstract

Organisation of institutional environments (emergency hospitals), with special focus on the medication process and institutional pharmaceutical care (continuum of care).

Objective

Students understand the concept of continuum of care and its practical implementation. They know the medication process within an institutional environment. They are able to find the necessary information and deal with problems in connection with pharmaceuticals, to evaluate them and to communicate and documentate their findings adequately. They know how a hospital is organised (procedures, possible problems), responsibilities of the different members of the staff and, most importantly, what the function of a hospital pharmacy is.

Content

Principals of the organisation of institutional environments (emergency hospitals), with special focus on medication processes and institutional pharmaceutical care (circulation of medication, continuum of care). Hygiene regulations, medical products, applications, drug formulations, patient files, SOAP notes, kardex study. Participation at interdisciplinary visits, internal trainings and doctors’ reports as well as visitation of the emergency room. Drug interaction, generic substitution, quality management and pharmacovigilance.
### Key for Type

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

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

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Data Science Master

Core Courses

Data Analysis

Information and Learning

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
- What is data?
- Bayesian Learning
- Computational learning theory

Supervised learning:
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

Unsupervised learning:
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

227-0423-00L Neural Network Theory W 4 credits 2V+1U H. Bölcskei

Abstract

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

Objective

After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

Content

1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

Lecture notes

Detailed lecture notes are available on the course webpage https://www.mins.ee.ethz.ch/teaching/int/

Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

Statistics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3621-00L</td>
<td>Fundamentals of Mathematical Statistics</td>
<td>W</td>
<td>10</td>
<td>4V+1U</td>
<td>S. van de Geer</td>
</tr>
</tbody>
</table>
The course covers the basics of inferential statistics.

### Data Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>263-3010-00L</td>
<td>Big Data</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>G. Fourny</td>
</tr>
</tbody>
</table>

#### Abstract

The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.

This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as “Big Data.” This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the “fourth paradigm”.

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that’s 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today’s technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRIL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, …)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

#### Literature

Large scale analytics and machine learning are outside of the scope of this course. Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3845-00L</td>
<td>Data Management Systems</td>
<td>W</td>
<td>8 credits</td>
<td>3V+1U+3A</td>
<td>G. Alonso</td>
</tr>
</tbody>
</table>

#### Abstract

The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you’re ready for this class or not, please consult the instructor.
252-0417-00L Randomized Algorithms and Probabilistic Methods

Abstract
Las Vegas & Monte Carlo algorithms: inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, SSAT, card shuffling, random walks

Objective
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.

Content
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Lecture notes
Yes.

Literature

Prerequisites / notice
Control systems (227-0216-00L) or equivalent.

252-1407-00L Algorithmic Game Theory

Abstract
Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computing systems without central control. The course discusses algorithmic aspects of game theory.

Objective
Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.

Content
The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don’t care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

Outline:
- Introduction to classic game-theoretic concepts.
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity.
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization.
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the ‘Price of Anarchy’).
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium.
- Selected current research topics, such as Google’s Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

Lecture notes
Lecture notes will be usually posted on the website shortly after each lecture.


Prerequisites / notice
Several copies of both books are available in the Computer Science library.

Literature
- “Game Theory and Strategy”, Philip D. Straffin, The Mathematical Association of America, 5th printing, 2004
- Several views of both books are available in the Computer Science library.
- Audience: Although this is a Computer Science course, we encourage the participation from all students who are interested in this topic.
- Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

252-1414-00L System Security

Abstract
The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers individual system’s aspects starting with tamperproof or tamperresistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

252-3005-00L Natural Language Processing

Number of participants limited to 400.
Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>ECTS</th>
<th>Objective</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>261-5130-00L</td>
<td>Research in Data Science</td>
<td>W</td>
<td>6</td>
<td>13A</td>
<td>Only for Data Science MSc.</td>
<td>Independent work under the supervision of a core or adjunct faculty of data science. Only students who have passed at least one core course in Data Management and Processing, and one core course in Data Analysis can start with a research project.</td>
</tr>
<tr>
<td>263-0006-00L</td>
<td>Algorithms Lab</td>
<td>W</td>
<td>8</td>
<td>4P+3A</td>
<td>A. Steger, E. Welzl</td>
<td>Independent work under the supervision of a core or adjunct faculty of data science. Project done under supervision of an approved professor.</td>
</tr>
<tr>
<td>263-0009-00L</td>
<td>Information Security Lab</td>
<td>W</td>
<td>8</td>
<td>2V+1U+3P+1A</td>
<td>K. Paterson, S. Capkun, D. Hofheinz, A. Perrig, S. Shinde</td>
<td>This InterFocus Course will provide a broad, hands-on introduction to Information Security, introducing adversarial thinking and security by design as key approaches to building secure systems. The course is organised in two-week segments. In each segment, a new concept from Information Security will be introduced. The overall scope will be broad, including cryptography, protocol design, network security, system security.</td>
</tr>
<tr>
<td>263-2400-00L</td>
<td>Reliable and Trustworthy Artificial Intelligence</td>
<td>W</td>
<td>6</td>
<td>2V+2U+1A</td>
<td>M. Vechev</td>
<td>Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting advances that bring us closer to constructing such models.</td>
</tr>
<tr>
<td>263-2800-00L</td>
<td>Design of Parallel and High-Performance Computing</td>
<td>W</td>
<td>9</td>
<td>3V+2U+3A</td>
<td>T. Hoefler, M. Püschel</td>
<td>Advanced topics in parallel and high-performance computing. Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.</td>
</tr>
</tbody>
</table>

Reinforcement learning (RL) has been in the limelight of many recent breakthroughs in artificial intelligence. This course focuses on

263-3210-00L  Deep Learning   W  8 credits  3V+2U+2A  F. Perez Cruz, A. Lucchi

Deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/s19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/lectures/pai-f18

263-5210-00L  Probabilistic Artificial Intelligence   W  8 credits  3V+2U+2A  A. Krause

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/lectures/pai-f18

263-5255-00L  Foundations of Reinforcement Learning   W  5 credits  2V+2A  N. He

This course aims to provide students with an advanced introduction of RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, students will be able to
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover "new" applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

**Computer Vision**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-5902-00L</td>
<td>8 credits</td>
<td>3V+1U+3A</td>
<td>The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.</td>
</tr>
</tbody>
</table>

**Objective**

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

**Content**

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition.

**Applied Analysis of Variance and Experimental Design**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0625-01L</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
</tr>
</tbody>
</table>

**Objective**

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

**Content**

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Literature**


**Algebraic Methods in Combinatorics**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3556-64L</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.</td>
</tr>
</tbody>
</table>

**Objective**

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

**Literature**

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

**Probability Theory**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3601-00L</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned: Basics in measure theory, series of independent random variables, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).</td>
</tr>
</tbody>
</table>

**Objective**

Basics of probability theory and the theory of stochastic processes in discrete time

**Content**

This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned: Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

**Lecture notes**

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

**Prerequisites**

Students are expected to have a mathematical background and should be able to write rigorous proofs.
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Former course title: Mathematical Optimization.

Prerequisites / notice
Solid background in linear algebra.

Abstract

The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

Content

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).

Generation of uniform random variables. Generation of random variables with arbitrary distributions (quantile transform, accept-reject, importance sampling), simulation of Gaussian processes and diffusions. The precision of simulations, methods for variance reduction.

Introduction to Markov chains and Markov chain Monte Carlo (Metropolis-Hastings, Gibbs sampler, Hamiltonian Monte Carlo, reversible jump MCMC).

Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.

Content

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).

Generation of uniform random variables. Generation of random variables with arbitrary distributions (quantile transform, accept-reject, importance sampling), simulation of Gaussian processes and diffusions. The precision of simulations, methods for variance reduction.

Introduction to Markov chains and Markov chain Monte Carlo (Metropolis-Hastings, Gibbs sampler, Hamiltonian Monte Carlo, reversible jump MCMC).


Lecture notes

A script will be available in English.

Literature

P. Glasserman, Monte Carlo Methods in Financial Engineering.


401-3627-00L High-Dimensional Statistics W 4 credits 2V P. L. Bühlmann

Abstract

“High-Dimensional Statistics” deals with modern methods and theory for statistical inference when the number of unknown parameters is much larger than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

Objective

Knowledge of methods and basic theory for high-dimensional statistical inference

Content

Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

Literature


Prerequisites / notice

Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

Abstract

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Former course title: Mathematical Optimization.

Prerequisites / notice

Solid background in linear algebra.

Abstract

This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

Objective

Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

Content

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).

Generation of uniform random variables. Generation of random variables with arbitrary distributions (quantile transform, accept-reject, importance sampling), simulation of Gaussian processes and diffusions. The precision of simulations, methods for variance reduction.

Introduction to Markov chains and Markov chain Monte Carlo (Metropolis-Hastings, Gibbs sampler, Hamiltonian Monte Carlo, reversible jump MCMC).


Lecture notes

A script will be available in English.

Literature

P. Glasserman, Monte Carlo Methods in Financial Engineering.


Prerequisites / notice

Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

Abstract

This is the course unit with former course title “Regression”.

Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).

Abstract

401-3627-00L High-Dimensional Statistics W 4 credits 2V P. L. Bühlmann

“High-Dimensional Statistics” deals with modern methods and theory for statistical inference when the number of unknown parameters is much larger than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

Objective

Knowledge of methods and basic theory for high-dimensional statistical inference

Content

Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

Literature


Prerequisites / notice

Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

Abstract

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Former course title: Mathematical Optimization.

Prerequisites / notice

Solid background in linear algebra.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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401-4623-00L Time Series Analysis

**W 6 credits 3G F. Balabdaoui**

*Does not take place this semester.*

**Abstract**
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

**Objective**
The goal of the course is to have a a good overview of the different types of time series and the approaches used in their statistical analysis.

**Content**
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

**Literature**
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

**Prerequisites / notice**
Basic knowledge in probability and statistics

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401-4944-20L Mathematics of Data Science

**W 8 credits 4G A. Bandeira**

**Abstract**
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

**Objective**
Introduction to various mathematical aspects of Data Science.

**Content**
These topics lie in overlaps of (Applied) Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Each lecture will feature a couple of Mathematical Open Problem(s) related to Data Science. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

**Lecture notes**

**Prerequisites / notice**
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

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402-0461-00L Quantum Information Theory

**W 8 credits 3V+1U P. Kammerlander**

**Abstract**
The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

**Objective**
By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

**Content**
Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties. Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

**Lecture notes**
Distributed via moodle.

**Literature**
- Nielsen and Chuang, Quantum Information and Computation
- Preskill, Lecture Notes on Quantum Computation
- Wilde, Quantum Information Theory
- Watrous, The Theory of Quantum Information
2V+1U+1A
Deep Learning in Artificial and Biological Neuronal Systems
Number of participants limited to 75.

Objective
The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to (a) engage in presentations and active in-class discussion, (b) work on problem-sets exemplifying the use of educational data mining techniques, and (c) undertake a final course project with feedback from instructors.

Content
The course will start with a general introduction to AI, where we will cover supervised and unsupervised learning techniques (e.g., classification and regression models, feature selection and preprocessing of data, clustering, dimensionality reduction, and text mining techniques) with a focus on application of these techniques in educational data mining. After the introduction of the basic methodologies, we will continue with the most relevant applications of AI in educational technologies (e.g., intelligent tutoring and student personalization, scaffolding open-ended discovery learning, socially-aware AI and learning at scale with AI systems). In the final part of the course, we will cover challenges associated with using AI in student-facing settings.

Lecture notes
Lecture slides will be made available at the course Web site.

Literature
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

Prerequisites / notice
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

227-2210-00L

Computer Architecture
W 8 credits 6G+1A O. Mutlu

Abstract
Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective
We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multi-core processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g., graph analytics, bioinformatics, machine learning), etc.

Content
The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

Lecture notes
All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

Literature
We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major Computer Architecture and related conferences and journals.

Prerequisites / notice

Interdisciplinary Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>227-1033-00L</td>
<td>Neuroromorphic Engineering I</td>
<td>W</td>
<td>6 credits</td>
<td>2V+3U</td>
<td>T. Deibrueck, G. Indiveri, S.-C. Liu</td>
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Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retina and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Particular: The course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

227-0421-00L

Deep Learning in Artificial and Biological Neuronal Networks
W 4 credits 3G B. Grewa

Number of participants limited to 75.

Abstract
Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective
The course will cover supervised and unsupervised learning techniques (e.g., classification and regression models, feature selection and preprocessing of data, clustering, dimensionality reduction and text mining techniques) with a focus on application of these techniques in educational data mining. After the introduction of the basic methodologies, we will continue with the most relevant applications of AI in educational technologies (e.g., intelligent tutoring and student personalization, scaffolding open-ended discovery learning, socially-aware AI and learning at scale with AI systems). In the final part of the course, we will cover challenges associated with using AI in student-facing settings.

Content
The course will start with a general introduction to AI, where we will cover supervised and unsupervised learning techniques (e.g., classification and regression models, feature selection and preprocessing of data, clustering, dimensionality reduction and text mining techniques) with a focus on application of these techniques in educational data mining. After the introduction of the basic methodologies, we will continue with the most relevant applications of AI in educational technologies (e.g., intelligent tutoring and student personalization, scaffolding open-ended discovery learning, socially-aware AI and learning at scale with AI systems). In the final part of the course, we will cover challenges associated with using AI in student-facing settings.

Lecture notes
Lecture slides will be made available at the course Web site.

Literature
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.

Prerequisites / notice
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.
Deep-Learning (DL) is a brain-inspired weak form of AI that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to ‘error backpropagation’ in order to train deep neuronal networks.
- use a diverse set of ANN regularizations methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

After this course students will be able to:
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.
- explain the basic ideas and concepts of plasticity in the mammalian brain.
- understand the origins of hierarchical learning and modern biological models.
- understand how ANNs have been shown to learn by interpreting and structuring the data provided by the external world.
- understand the limitations of ANN design and training algorithms compared to biological neuronal networks.
- understand the implications of these limitations for the development of future ANN training methods.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). These written documents will be graded and count as 40% for the final grade.

The participation in the course is subject to the following conditions:
1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

The course critically reviews central problems in Biomedicine and discusses the technical foundations and solutions for these problems.

**227-0945-00L**

**Cell and Molecular Biology for Engineers I**

This course is part I of a two-semester course.

**Abstract**

The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

**Objective**

After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

**Content**

Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). These written documents will be graded and count as 40% for the final grade.

**261-5100-00L**

**Computational Biomedicine**

The course critically reviews central problems in Biomedicine and discusses the technical foundations and solutions for these problems.

**Abstract**

The course critically reviews central problems in Biomedicine and discusses the technical foundations and solutions for these problems.
Comprehension and application of advanced portfolio theory
3 credits
University lecturers

Objective
Over the past years, rapid technological advancements have transformed classical disciplines such as biology and medicine into fields of
applied data science. While the sheer amount of the collected data often makes computational approaches inevitable for analysis, it is
the domain specific structure and close relation to research and clinic, that call for accurate, robust and efficient algorithms. In this course we
will critically review central problems in Biomedicine and will discuss the technical foundations and solutions for these problems.

Content
The course will consist of three topic clusters that will cover different aspects of data science problems in Biomedicine:
1) Algorithms and data structures for the efficient representation, search, comparison, composition and compression of large sets of strings, mostly
originating from DNA or RNA Sequencing. This includes genome assembly, efficient index data structures for strings and graphs, alignment
techniques as well as quantitative approaches.
2) Statistical models and algorithms for the assessment and functional analysis of individual genomic variations, this includes the
identification of variants, prediction of functional effects, imputation and integration problems as well as the association with clinical
phenotypes.
3) Models for organization and representation of large scale biomedical data. This includes ontology concepts, biomedical databases,
sequence annotation and data compression.

Prerequisites / notice

261-5112-00L Algorithms and Data Structures for Population Scale Genomics W 3 credits 2G

Abstract
Research in Biology and Medicine have been transformed into disciplines of applied data science over the past years. Not only size and
inherent complexity of the data but also requirements on data privacy and complexity of search and access pose a wealth of new research
questions.

Objective
Over the duration of the semester, the course will cover three main topics. Each of the topics will consist of 70-80% lecture content and 20-
30% seminar content.
1) Algorithms and data structures for text and graph compression. Motivated through applications in compressive genomics, the course will
cover succinct indexing schemes for strings, trees and general graphs, compression schemes for binary matrices as well as the efficient
representation of haplotypes and genomic variants.
2) Stochastic data structures and algorithms for approximate representation of strings and graphs as well as sets in general. This includes
winnowing schemes and minimizers, sketching techniques, (minimal perfect) hashing and approximate membership query data structures.
3) Data structures supporting encryption and data privacy. As an extension to data structures discussed in the earlier topics, this will
include secure indexing using homomorphic encryption as well as design for secure storage and distribution of data.

261-5111-00L Asset Management: Advanced Investments W 3 credits 2V

(University of Zurich)

Abstract
Comprehension and application of advanced portfolio theory

Objective
Comprehension and application of advanced portfolio theory

Content
The theoretical part of the lecture consists of the topics listed below.
- Standard Markowitz Model and Extensions MV Optimization, with Liabilities and CAPM.
- The Crux with MV
- Resampling, regression, Black-Litterman, Bayesian, shrinkage, constrained and robust optimization.
- Downside and Coherent Risk Measures
- Definition of risk measures, MV optimization under VaR and ES constraints.
- Risk Budgeting
- Equal risk contribution, most diversified portfolio and other concentration indices
- Regime Switching and Asset Allocation
- An introduction to regime switching models and its intuition.
- Strategic Asset Allocation
- Introducing a continuous-time framework, solving the HJB equation and the classical Merton problem.

636-0017-00L Computational Biology W 6 credits 3G+2A T. Vaughan

Abstract
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data.
Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand
this information in detail are introduced.

Objective
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using
computational tools. The main concepts introduced are:
* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics
Attendees will apply these concepts to a number of applications yielding biological insight into:
* epidemiology
* pathogen evolution
* macroevolution of species

Content
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments
from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS.
Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third,
we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss
methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylo dynamics, the aim of which is to understand and
quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a
phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and
evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution
provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application
both on paper and in silico as part of the exercises.

Lecture notes
Lecture slides will be available on moodle.
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-E. Fischer

Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between:

- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning

The students can understand the role of land processes and associated feedbacks in the climate system.


### 701-0023-00L Atmosphere

**Abstract**

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

**Objective**

Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

**Content**

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

**Lecture notes**

Written information will be supplied.

**Literature**


### 701-0473-00L Weather Systems

**Abstract**

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation: atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

**Objective**

The students are able to:

- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

**Content**

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation: atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

**Lecture notes**

Lecture notes and slides

**Literature**

Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

### 701-1251-00L Land-Climate Dynamics

**Number of participants limited to 36. Priority is given to the target groups:**

- Master Environmental Science,
- Master Atmospheric and Climate Science and
- PhD D-USYS

**Until September 20th, 2021. Waiting list will be deleted September 27th, 2021.**

The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy and water balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

**Objective**

The students can understand the role of land processes and associated feedbacks in the climate system.

**Lecture notes**

Powerpoint slides will be made available

**Prerequisites / notice**

Prerequisites: Introductory lectures in atmospheric and climate science

Atmospheric physics -> http://www.vzw.ethz.ch/Vorlesungsverzeichnis/lerneinheitPre.do?lerneinheitId=112225&semkez=2018W&ansicht=KATALOGDATEN&lderneinheitId=123546&lang=d en and/or

### 101-0417-00L Transport Planning Methods

**Abstract**

The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

**Objective**

- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

**Content**

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

**Lecture notes**

Moodle platform (enrollment needed)
Cartography III
GIS III
101-0491-00L Agent Based Modeling in Transportation
3G M. Balac
W 6 credits
Abstract
This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models’ current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.
Objective
At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform practical transportation studies
Content
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:
1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained.
Here the open-source eqasim framework used at ETH Zurich to set up agent-based models will be introduced
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

Literature
Agent-based modeling in general
MATSim

Prerequisites / notice
Additional relevant readings, primarily scientific articles, will be recommended throughout the course.
There are no strict prerequisites in terms of which lectures the students should have previously attended. However, knowledge of basic statistical theory is expected, and experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

103-0227-00L Cartography III
W 5 credits
Abstract
This follow-up course proceeds to a complete Web map project and introduces in 3D and animated cartography.
Objective
This course enables students to plan, design and realize interactive Web map projects. The introduction to 3D and animated cartography also provides a general knowledge about animated 3D graphics.
Content
- Web mapping.
- Data processing.
- Interaction design.
- Graphical user interface.
- 3D cartography.
- Animated cartography.
- Video production.
Lecture notes
Handouts of the lectures and exercise documents are available on Moodle.
Prerequisites / notice
Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

103-0237-00L GIS III
W 5 credits
Abstract
The course deals with advanced topics in GIS, such as Business aspects and Legal issues; Geostatistics; Human-Computer Interaction; Cognitive Issues in GIS; Geosensors; Spatial Data Mining and Machine Learning for GIS.
Objective
Students will get a detailed overview of advanced GIS topics. They will work on a small project with geosensors in the lab and perform practical tasks relating to Geostatistics and Machine Learning.
Lecture notes
Lecture slides will be made available in digital form.

103-0717-00L Geoinformation Technologies and Analysis
W 6 credits
Abstract
Geoinformationstechnologien und -analysen für Fortgeschrittene: Mobile GIS; Web-GIS & Geo-Web-Services; Spatial Big Data; Zeitliche Aspekte in GIS; Analyse von Bewegungsdaten; Benutzerschnittstellen
Ubungen: Web-GIS-Semesterprojekt in Gruppenarbeit
Objective
Content
- Mobile GIS
- Web-GIS & Geo-Web-Services
- Spatial Big Data
- Zeitliche Aspekte in GIS
- Analyse von Bewegungsdaten
- Benutzerschnittstellen
Lecture notes
Vorlesungspräsentationen werden digital zur Verfügung gestellt.
Literature
Prerequisites / notice
GIS GZ
The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

The course will cover advanced topics in Internet routing and forwarding such as:

- Tunneling
- Hierarchical routing
- Traffic Engineering and Load Balancing
- Virtual Private Networks
- Quality of Service/Queueing/Scheduling
- Fast Convergence
- Network virtualization
- Network programmability (OpenFlow, P4)
- Network measurements

The course will be divided in two main blocks. The first block (~8 weeks) will interleave classical lectures with practical exercises and labs. The second block (~6 weeks) will consist of a practical project which will be performed in small groups (~3 students). During the second block, lecture slots will be replaced by feedback sessions where students will be able to ask questions and get feedback about their project. The last week of the semester will be dedicated to student presentations and demonstrations.

Lecture notes
Lecture notes and material will be made available before each course on the course website.

Literature
Relevant references will be made available through the course website.

Prerequisites / notice
Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

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

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

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies
- Adaptability and Flexibility
- Critical Thinking

The classic life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated.

The following topics are treated:

- Collective Risk Modeling
- Individual Claim Size Modeling
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tarification
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

Lecture notes
M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

Literature
M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications
http://ssrn.com/abstract=3822407

Prerequisites / notice
This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

Prerequisites: knowledge of probability theory, statistics and applied stochastic processes.
### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain A - Subject-specific Competencies | Techniques and Technologies | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain B - Method-specific Competencies | Decision-making | assessed |
| Domain B - Method-specific Competencies | Media and Digital Technologies | not assessed |
| Domain B - Method-specific Competencies | Problem-solving | assessed |
| Domain B - Method-specific Competencies | Project Management | not assessed |

### Taught competencies

| Domain C - Social Competencies | Communication | assessed |
| Domain C - Social Competencies | Cooperation and Teamwork | not assessed |
| Domain C - Social Competencies | Customer Orientation | not assessed |
| Domain C - Social Competencies | Leadership and Responsibility | not assessed |
| Domain C - Social Competencies | Self-presentation and Social Influence | not assessed |
| Domain C - Social Competencies | Sensitivity to Diversity | not assessed |
| Domain C - Social Competencies | Negotiation | not assessed |

| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| Domain D - Personal Competencies | Creative Thinking | not assessed |
| Domain D - Personal Competencies | Critical Thinking | not assessed |
| Domain D - Personal Competencies | Integrity and Work Ethics | not assessed |
| Domain D - Personal Competencies | Self-awareness and Self-reflection | not assessed |
| Domain D - Personal Competencies | Self-direction and Self-management | not assessed |

### Abstract

This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and models for extreme events such as natural or man-made catastrophes. The lecture covers reinsurance contracts, Experience and Exposure pricing, natural catastrophe modelling, solvency regulation, and insurance linked securities.

Topics covered include:
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

### Objective

This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

Topics covered include:
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

### Content

This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

Topics covered include:
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

### Lecture notes

Slides and lecture notes will be made available.

An excerpt of last year’s lecture notes is available here: https://sites.google.com/site/philipparbenz/reinsuranceanalytics

### Prerequisites / notice

Basic knowledge in statistics, probability theory, and actuarial techniques.

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### Abstract

Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

### Objective

Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes)
Content
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.
Topics include
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

Lecture notes
The course is based on different parts from different books as well as on original research literature.

Lecture notes will not be available.

Literature
Prerequisites / notice
Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)
Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.

For an overview of courses offered in the area of mathematical finance, see https://www.math.ethz.ch/imsf/education/education-in-stochastic-finance/overview-of-courses.html.

401-8905-00L Financial Engineering (University of Zurich) W 6 credits 4G
University lecturers

4G
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: MFOEC200
Mind the enrolment deadlines at UZH:

Abstract
This lecture is intended for students who would like to learn more on equity derivatives modelling and pricing.

Objective
Quantitative models for European option pricing (including stochastic volatility and jump models), volatility and variance derivatives, American and exotic options.

Content
After introducing fundamental concepts of mathematical finance including no-arbitrage, portfolio replication and risk-neutral measure, we will present the main models that can be used for pricing and hedging European options e.g. Black-Scholes model, stochastic and jump-diffusion models, and highlight their assumptions and limitations. We will cover several types of derivatives such as European and American options, Barrier options and Variance Swaps. Basic knowledge in probability theory and stochastic calculus is required. Besides attending class, we strongly encourage students to stay informed on financial matters, especially by reading daily financial newspapers such as the Financial Times or the Wall Street Journal.

Lecture notes
Script.

Prerequisites / notice
Basic knowledge of probability theory and stochastic calculus.

851-0252-13L Network Modeling W 3 credits 2V
C. Stadtfeld, V. Amati

Particularly suitable for students of D-INFK and in the MSc Data Science

Students are required to have basic knowledge in inferential statistics, such as regression models.

Abstract
Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks. Statistical and numerical methods have been developed to fit these models to empirical data. Emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

Objective
Students will be able to develop hypotheses that relate to the structures and dynamics of (social) networks, and tests those by applying advanced statistical network methods such as exponential random graph models (ERGMs) and stochastic actor-oriented models (SAOMs). Students will be able to explain and compare various network models, and develop an understanding of how those can be fit to empirical data. This will enable students to independently address research questions from various social science fields.
Content

The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.

Workshop & Lecture Series on the Law & Economics

**851-0735-09L** Workshop & Lecture Series on the Law & Economics  W  2 credits  2S  S. Bechtold, H. Gersbach of Innovation

**Abstract**

This series is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. & beyond.

**Objective**

After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas.

**Content**

The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented.

**Lecture notes**

Papers discussed in the workshop and lecture series are posted in advance on the course web page.

**Literature**

- Suzanne Scotchmer, Innovation and Incentives, 2004
- Bronwyn Hall / Nathan Rosenberg (eds.), Handbook of the Economics of Innovation, 2 volumes, Amsterdam 2010
- Bronwyn Hall / Dietmar Harhoff, Recent Research on the Economics of Patents, 2011

**Taught competencies**

Domain A - Subject-specific Competencies
- Concepts and Theories
  assessed

Domain B - Method-specific Competencies
- Analytical Competencies
  assessed
- Problem-solving
  assessed

Domain C - Social Competencies
- Communication
  assessed

Domain D - Personal Competencies
- Creative Thinking
  assessed
- Critical Thinking
  assessed

**851-0252-15L** Network Analysis  W  3 credits  2V  U. Brandes

**Abstract**

Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.

**Objective**

Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis. In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

**Content**

The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

- Empirical Research and Network Data
- Macro and Micro Structure
- Centrality
- Roles
- Cohesion

**Lecture notes**

Lecture notes are distributed via the associated course moodle.

**Literature**


**851-0760-00L** Building a Robot Judge: Data Science for Decision- W  3 credits  2V  E. Ash
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter course "Wahrscheinlichkeitstheorie". (A possible alternative to the above English textbook are the (German) lecture notes for the standard very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard

Also, several guest lectures will provide in-depth insights into specific current real-world network-security topics.
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

### Data Science Lab

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3300-00L</td>
<td>Data Science Lab</td>
<td>O</td>
<td>14</td>
<td>9P</td>
<td>C. Zhang, V. Boeva, R. Cotterell, J. Vogt, F. Yang</td>
</tr>
</tbody>
</table>

**Abstract**

In this class, we bring together data science applications provided by ETH researchers outside computer science and teams of computer science master's students. Two to three students will form a team working on data science/machine learning-related research topics provided by scientists in a diverse range of domains such as astronomy, biology, social sciences etc.

**Objective**

The goal of this class if for students to gain experience of dealing with data science and machine learning applications “in the wild”: Students are expected to go through the full process starting from data cleaning, modeling, execution, debugging, error analysis, and quality/performance refinement.

**Prerequisites / notice**

Prerequisites: At least 8 KP must have been obtained under Data Analysis and at least 8 KP must have been obtained under Data Management and Processing.

### Seminar

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>J. M. Buhmann, R. Cotterell, J. Vogt, F. Yang</td>
</tr>
</tbody>
</table>

**Abstract**

In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.

**Objective**

The seminar "Advanced Topics in Machine Learning" familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

**Content**

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

**Literature**

The papers will be presented in the first session of the seminar.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3504-00L</td>
<td>Hardware Acceleration for Data Processing</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>G. Alonso</td>
</tr>
</tbody>
</table>

**Abstract**

The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.
The goal of this seminar is to gain experience with machine learning research and foster interdisciplinary thinking.

0 credits

Review of some non-standard regression models and the statistical properties of estimation methods in such models.

Research colloquium

Foundations of Data Science Seminar

Beyond iid Learning: Causality, Dynamics, and Interactions

Number of participants limited to 60.

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Many machine learning problems go beyond supervised learning on independent data points and require an understanding of the underlying causal mechanisms, the interactions between the learning algorithms and their environment, and adaptation to temporal changes. The course highlights some of these challenges and relates them to state-of-the-art research.

The seminar will be divided into two parts. The first part summarizes the basics of statistical learning theory, game theory, causal inference, and dynamical systems in four lectures. This sets the stage for the second part, where distinguished speakers will present selected aspects in greater detail and link them to their current research.

Keywords: Causal inference, adaptive decision-making, reinforcement learning, game theory, meta learning, interactions with humans.

Further information will be published on the course website: https://beyond-iid-learning.xyz/

Students taking this seminar should have the necessary background in systems and low level programming.

In the following is the tentative material that will be read and studied by each pair of students (all the items listed below are available through the ETH electronic library or arXiv). Some of the items might change.

8. "Linear regression with shuffled data: statistical and computation limits of permutation recovery" by A. Pananjady, M. Wainwright and T. A. Courtade , 2018, IEEE transactions in Information Theory, Volume 64, 3286-3300
9. "Linear regression without correspondence" by D. Hsu, K. Shi and X. Sun, 2017, NIPS
11. "Uncoupled isotonic regression via minimum Wasserstein deconvolution" by P. Rigollet and J. Weed, 2019, Information and Inference, Volume 00, 1-27

Prerequisites / notice

Students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

GESS Science in Perspective
<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>261-0800-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

The minimal prerequisites for the Master's thesis registration are:

- Completed Bachelor's program
- All additional requirements completed (additional requirements, if any, are listed in the admission decree)
- Minimum degree requirements fulfilled of the course categories Data Analysis and Data Management and overall 50 credits obtained in the course category Core Courses
- Data Science Lab (14 credits) completed

Abstract
The Master's thesis concludes the study program and demonstrates the students' ability to use the knowledge and skills acquired during Master's studies to solve a complex data science problem.

Objective
To work independently and to produce a scientifically structured work.

**Data Science Master - Key for Type**

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

**Key for Hours**

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

**ECTS**
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Doctoral Department of Architecture


## Doctoral and Post-Doctoral Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>M. Stauffacher, C. E. Pohl, B. Vienni Baptista</td>
</tr>
</tbody>
</table>

All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture. The lecture takes place if a minimum of 12 students register for it.

**Abstract**

This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.

**Objective**

Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

**Content**

The seminar covers the following topics:

1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

**Literature**

Literature will be made available to the participants.

The following open access article builds a core element of the course:


Further, this collection of tools will be used: [https://naturalsciences.ch/topics/co-producing_knowledge](https://naturalsciences.ch/topics/co-producing_knowledge)

**Prerequisites / notice**

Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00): 29 September, 27 October, 10 November, 24 November, 8 December

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>064-0005-21L</td>
<td>Advanced Topics in History and Theory of Architecture: Entry Points - Reading Seminar</td>
<td>W</td>
<td>1 credit</td>
<td>1K</td>
<td>P. Ursprung, T. Avermaete, M. Delbeke, L. Stalder</td>
</tr>
</tbody>
</table>

**Abstract**

The seminar will consist of a series of collective readings of selected texts.

**Objective**

Knowledge of relevant texts in contemporary theory.

Capacity to critically discuss methods and discourses.

**Lecture notes**

Scans of selected texts for discussion and exercises will be provided at the beginning of HS 2020 on the course website:


**Prerequisites / notice**

The seminar addresses the fellows of the Doctoral Program in History and Theory of Architecture. All other doctoral students of the Faculty of Architecture are welcome.

**Taught competencies**

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptable and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>064-0013-21L</td>
<td>Research Methods in the History and Theory of Architecture</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>C. Rachele</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to methodological approaches in the history and theory of architecture; presentation and discussion of individual doctoral projects.
The two-semester course in the first year of the doctoral program in the history and theory of architecture has a twofold objective: First, method sessions on central approaches in the history and theory of architecture provide a methodological basis for the doctorate at the Institute GTA. Secondly, in “practice” sessions, the doctoral students gain experience in their individual research projects and guidance for the production of the Research Plan they have to present at the end of the first year.

Content

“Again, if a thing can be done adequately by means of one, it is superfluous to do it by means of several; for we observe that nature does not employ two instruments where one suffices.”


The methodology of humanistic research grows more complex with every academic generation: it presents a complex thicket of epistemological frameworks and practical strategies rather than a straightforward array of tools. In the omnivorous field of architectural history and theory, the scholar faces a yet more multi-faceted array of possible approaches to any individual research subject. This course considers the variety of available strategies for the creation of architectural histor(ies) and theor(ies) as an opportunity for intellectual inquiry distinctive to our discipline. Through close and prolonged study of a range of historically significant or methodologically innovative writing, we will deepen our understanding both of how other historians have structured their work as well as refine each student’s developing research methodology.

The course, held over two semesters, combines a traditional doctoral theory seminar with a practical writing workshop: we will alternate reading-based discussions with working sessions directed towards the development of the research proposal to be submitted at the end of the first year.

Due to the intensive nature of the course, active class participation is required for doctoral students and all in-presence attendees. Students attending individual sessions in a listening capacity are requested to utilize the hybrid option.

The course schedule will be available at the beginning of HS 2021 on the course website: https://doctoral-program.gta.arch.ethz.ch/courses/research-methods

Lecture notes

Please note doctoral program courses begin the third week of the semester.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Project Management

Domain B - Method-specific Competencies

- Communication
- Cooperation and Teamwork

Domain C - Social Competencies

- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

Domain D - Personal Competencies

- Self-awareness and Self-reflection
- Self-direction and Self-management


Abstract

Advanced PhD candidates of urban studies, urban and landscape design and urban sociology report about their experiences and insights in the concrete application of methods utilized for their research and scientific publications. Discussion of ongoing individual work, methodological questions, critical perspectives on urban and landscape design and city’s relation to society.

Objective

The seminar seeks to provide participants with a differentiated knowledge of methods in the field of the urbanism. Furthermore, it provides a platform to exchange contemporary urban research experiences across disciplinary boundaries, drawing from different geographies of knowledge production. Possible meta-themes include modes of data assessment in urban studies, ways of progressing from hypothesis to synthesis, and research by design as method.

Content

The format will provide an overarching methodological meta-theme, to be defined prior to the event. One external guest critic will be invited. In this case, each presentation will conclude with a discussion round, providing sufficiently detailed feedback for every doctoral candidate.

Prerequisites / notice

The seminar is joint-organized by the chairs of the professors H. Klumper, Ch. Girot, G. Vogt and M. Angell (who in HS18 is mainly responsible for the course (one full-day event in the academic semester)).

Participants in both cases will be expected to submit single-page abstracts of their papers in advance and to make a presentation of app. 20 minutes at the colloquium. The discussion rounds will be moderated by the organizing professor and the invited guests.

Enrolment on agreement with the lecturer only.

064-00015-21L PhD Colloquium Theory of Information Technology for Architects ■ W 2 credits 2K L. Hovestadt

Abstract

Information technology plays an increasingly important role in research. To meet this challenging development, it is not only important to acquire respective skills, but also to consider and understand information technology in what sets it apart from other gestalts of technics (like mechanics, dynamics, or thermodynamics).

Objective

The aim of this colloquium is to counter an observable tendency, that proportional to the degree in which students master practical skills in computing, they increasingly submit uncritically, in their understanding and framing of problems, to the dictation of schemata and templates implemented by technical systems.

Content

The starting point for this colloquium is to comprehend computing not in terms of skills, but as a literacy which we can experience emerging today. Like in the case of writing as well, computing cannot exhaustively be reduced to either logics, grammar, arithmetic, or analytics. Rather, computation, if comprehended as a literacy, relates to any of the established categories of learning and raises questions of an architectonic kind. This colloquium draws from the principal richness of cultural forms of knowing and learning and thematizes approaches to formulate a theoretical stance on information technology for architects which is driven by and resting on the actual reality of computability today. In this, it is complementary to those theory courses on technology offered by the historical disciplines at ETH.

Prerequisites / notice

To benefit from this course, you should have a practical affinity to technics, as well as an abstract interest in information technology in its comprehensive cultural context.

064-0025-21L Introduction to Computational Research in Architecture, Engineering, Fabrication and Construction ■ W 2 credits 3K P. Block

Abstract

The PhD-level course (primarily for A&T PhDs) will introduce computational methods for architecture, engineering, fabrication & construction, incentivising computational literacy. Students learn the theoretical background and basic implementation details of fundamental data structures and algorithms, and to solve realworld problems using the COMPAS framework and other open-source libraries.

**Objective**
Understand the scope and relevance of computational methods for architecture and engineering research and practice, ii) the theoretical background of fundamental data structures, iii) the basic principles of algorithmic design; iv) implement basic versions of prevalent algorithms related to architectural geometry, structural design, robotic assembly, volumetric modeling & 3D printing, high-performance computation; v) use sophisticated algorithms available through open-source libraries to solve real-world problems; and, vi) use common CAD tools as interfaces to self-implemented solutions.

**Content**
Course consists of a few lectures, several tutorials and project-based exercises. Topics include:
- intro Python programming
- intro COMPAS open-source framework (https://compas-ev.github.io)
- intro to geometry processing, data structures, topology, numerical computation
- domain-specific case studies (e.g. on architectural geometry, structural design, robotic assembly, volumetric modeling & 3D printing, high-performance computation)

**Prerequisites / notice**
Priority is given to PhD students.

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**101-0139-00L Scientific Machine and Deep Learning for Design and Construction in Civil Engineering**

**Abstract**
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction in civil engineering. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

**Objective**
This course aims to provide graduate level introduction into Machine and especially scientific Machine Learning for applications in the design and construction phases of projects from civil engineering.

Upon completion of the course, the students will be able to:
1. understand main ML background theory and methods
2. assess a problem and apply ML and DL in a computational framework accordingly
3. Incorporating scientific domain knowledge in the SciML process
4. Define, Plan, Conduct and Present a SciML project

**Content**
The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
1. Fundamentals of Machine and Deep Learning (ML / DL)
2. Incorporation of Domain Knowledge into ML and DL
3. ML training, validation and testing pipelines for academic and research projects

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a “hands-on” feel for the course topics.

**Lecture notes**
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

**Literature**
Suggested Reading:
- Marc Peter Deisenroth, A Alois Faisal, and Cheng Soon Ong Mathematics for Machine Learning

**Prerequisites / notice**
Familiarity with MATLAB and / or Python is advised.

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**351-0778-00L Discovering Management**

**Abstract**
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

**Objective**
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

**Content**
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a “lecture-style” approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a “pitch” with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

**Lecture notes**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.
### Taught Competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies          | Communication         | assessed |
| Domain D - Personal Competencies        | Creative Thinking     | assessed |

### Abstract
This course will review some critical reflections on scientific epistemology, challenging prevalent notions of scientific objectivity. We will start with German critiques from the first half of the 20th century (Heidegger, Husserl, Frankfurt school), go on to French critiques from the second half (Foucault, Latour), and conclude with recent feminist and post-colonial critiques.

### Objective
The students will be able to formulate and criticize arguments engaging with prevalent notions of contemporary scientific objectivity. They will be able to critically reflect on the authority of the knowledge that they learn and produce.

### Doctoral Department of Architecture - Key for Type

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<tr>
<th>Key</th>
<th>Description</th>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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### Key for Hours

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<th>Key</th>
<th>Description</th>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

### ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
After successfully completing this course the students will be able to:

- Understand the mechanics of and design an isolated structure.
- Behavior and modeling of isolation devices, response of structures with isolation devices.
- Design approaches and code requirements

All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture. The lecture takes place if a minimum of 12 students register for it.

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature

Further, this collection of tools will be used: https://naturalsciences.ch/topics/co-producing_knowledge

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.

Dates (Wednesdays, 8h15-12h00): 29 September, 27 October, 10 November, 24 November, 8 December

Course Catalogue of ETH Zurich

101-0191-00L Seismic and Vibration Isolation W 2 credits 1G M. Vassiliou

Abstract
This course will cover the analysis and design of isolation systems to mitigate earthquakes and other forms of vibrations. The course will cover:
1. Conceptual basis of seismic isolation, seismic isolation types, mechanical characteristics of isolators.
3. Design approaches and code requirements

Objective
After successfully completing this course the students will be able to:
1. Understand the mechanics of and design isolator bearings.
2. Understand the dynamics of and design an isolated structure.

Content
1. Introduction: Overview of seismic isolation; review of structural dynamics and earthquake engineering principles. Viscoelastic behavior.
2. Linear theory of seismic isolation
3. Types of seismic isolation devices - Modelling of seismic isolation devices – Nonlinear response analysis of seismically isolated structures in Matlab
4. Behavior of rubber isolators under shear and compression
5. Behavior of rubber isolators under bending
6. Buckling and stability of rubber isolators
7. Code provisions for seismically isolated buildings

Lecture notes
The electronic copies of the learning material will be uploaded to ILIAS and available through myStudies. The learning material includes: reading material, and (optional) exercise problems and solutions.

Literature
There is no single textbook for this course. However, most of the lectures are based on parts of the following books:
- Dynamics of Structures, Theory and Applications to Earthquake Engineering, 4th edition, Anil Chopra, Prentice Hall, 2017
- Design of seismic isolated structures: from theory to practice, Farzad Naeim and James M. Kelly, John Wiley & Sons, 1999
- Mechanics of rubber bearings for seismic and vibration isolation, James M. Kelly and Dimitrios Konstantinidis, John Wiley & Sons, 2011
- 101-0157-01 Structural Dynamics and Vibration Problems course, or equivalent, or consent of the instructor. Students are expected to know basic modal analysis, elastic spectrum analysis and basic structural mechanics.

101-0121-00L Fatigue and Fracture in Materials and Structures W 4 credits 3G E. Ghafoori, A. Taras

Abstract
The fundamentals in fatigue and fracture mechanics, which are used in different engineering disciplines (e.g., for mechanical, aerospace, civil and material engineers) will be discussed. The focus will be on fundamental theories (based on fracture mechanics) that model fatigue damage and crack propagation.
In this course, the students will learn:
- Linear elastic and plastic-fracture mechanics.
- Analytical methods for fatigue-related calculations.
- Modern computer-based techniques (using ABAQUS Finite Element Package) to simulate cracks in both bulk materials and bonded joints/interfaces.
- Laboratory fatigue and fracture tests on details with cracks.

The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered in this course are:

I) Fatigue of materials:
- Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
- Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner's damage rule.
- Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

II) Fracture mechanics:
- Elastic fracture mechanics (EFM): limits of EFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
- Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
- Fatigue crack growth (FCG): FCG models, Paris’ law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

III) Introduction to cohesive zone models (CZMs):
- Advantages and disadvantages of CZMs compared to fracture mechanics.
- Different bond-slip models for the bonded joints/interfaces.

IV) Computer laboratory to simulate cracks and debonding problems:
- Finite Element (FE) modeling of complex details with cracks.
- FE simulations of debonding problems using CZMs.
- Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

V) Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

VI) Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and “Laboratory Competition”. The students will:
- Visit different small-scale and large-scale fatigue testing equipment.
- Get to know different ongoing fatigue- and fracture-related projects.
- Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
- Compare the experimental results with their own calculations (from the fracture theories).
- “Laboratory Competition” at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded a prize.

Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.


1 credit

This doctoral seminar organised by the D-BAUG platform on data science and machine learning aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and “Laboratory Competition”. The students will:
- Visit different small-scale and large-scale fatigue testing equipment.
- Get to know different ongoing fatigue- and fracture-related projects.
- Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
- Compare the experimental results with their own calculations (from the fracture theories).
- “Laboratory Competition” at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded a prize.

Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.


1 credit
With the increasing amount of data collected in various domains, the importance of data science in many disciplines, such as infrastructure monitoring and management, transportation, spatial planning, structural and environmental engineering, has been increasing. The field is constantly developing further with numerous advances, extensions and modifications. The course aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).

Each student will select a paper that is relevant for his/her research and present it in the seminar, putting it into context, analyzing the assumptions, the transferability and generalizability of the proposed approaches. The students will also link the research content of the selected paper to the own research, evaluating the potential of transferring or adapting it. If possible and applicable, the students will also implement the adapted algorithms. The students will work in groups of three students, where each of the three students will be reading each other's selected papers and providing feedback to each other.

This doctoral seminar is intended for doctoral students affiliated with the Department of Civil, Environmental and Geomatic Engineering.

Participants are expected to possess elementary skills in statistics, data science and machine learning, including both theory and practical modelling and implementation. The seminar targets students who are actively working on related research projects.

### 101-0139-00L Scientific Machine and Deep Learning for Design and Construction in Civil Engineering

**Abstract**

This course will present methods of scientific machine and deep learning (ML / DL) for applications in design and construction in civil engineering. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

**Objective**

This course aims to provide graduate level introduction into Machine and especially scientific Machine Learning for applications in the design and construction phases of projects from civil engineering.

Upon completion of the course, the students will be able to:

1. understand main ML background theory and methods
2. assess a problem and apply ML and DL in a computational framework accordingly
3. incorporating scientific domain knowledge in the SciML process
4. Define, Plan, Conduct and Present a SciML project

**Content**

The topics to be covered are:

1. Fundamentals of Machine and Deep Learning (ML / DL)
2. ML training, validation and testing pipelines for academic and research projects
3. Incorporation of Domain Knowledge into ML and DL

A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a “hands-on” feel for the course topics.

**Lecture notes**

The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

**Literature**

Suggested Reading:

Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong Mathematics for Machine Learning


S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016

O. Martin: Bayesian analysis with python. Packt Publishing Ltd, 2016

**Prerequisites / notice**

Familiarity with MATLAB and / or Python is advised.

### 101-0522-11L Doctoral Seminar: Computational Science in Civil, Env. and Geomatic Engineering

**Abstract**

The objective is to provide insight into current research efforts in computational sciences applied to the large variety of fields related to civil, environmental and geomatic engineering. This course consists of research talks from invited experts. It will provide a platform for discussion.

**Objective**

- broadening knowledge of numerical methods and simulation techniques across fields
- learn about potential of numerical modeling
- develop scientific writing skills

**Content**

Various topics related to modeling in the field of civil, environmental, and geomatic engineering.

**Doctoral Department of Civil, Environmental and Geomatic Engineering - Key for Type**

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

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
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<td>exercise</td>
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**ECTS**

European Credit Transfer and Accumulation System

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>376-1791-00L</td>
<td>Introductory Course in Neuroscience I (University of Zurich)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>University lecturers</td>
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<tr>
<td></td>
<td><em>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</em></td>
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<td><em>UZH Module Code: SPV0Y005</em></td>
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<td></td>
<td><em>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></em></td>
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<tr>
<td>Abstract</td>
<td>The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.</td>
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<tr>
<td>Objective</td>
<td>The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.</td>
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</tbody>
</table>
| Content    | 1) Human Neuroanatomy I&II  
2) Comparative Neuroanatomy  
3) Building a central nervous system I&II  
4) Synapses I&II  
5) Glia and more  
6) Excitability  
7) Circuits underlying Emotion  
8) Visual System  
9) Auditory & Vestibular System  
10) Somatosensory and Motor Systems  
11) Learning in artificial and biological neural networks |
| Prerequisites / notice | For doctoral students of the Neuroscience Center Zurich (ZNZ) |

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0927-00L</td>
<td>Rate-Controlled Separations in Fine Chemistry</td>
<td>W</td>
<td>6 credits</td>
<td>3V+1U</td>
<td>M. Mazzotti, V. Becattini</td>
</tr>
<tr>
<td>Abstract</td>
<td>The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.</td>
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<tr>
<td>Objective</td>
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<tr>
<td>Content</td>
<td>The class covers separation techniques that are central in the purification and downstream processing of chemicals and bio-pharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.</td>
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<tr>
<td>Lecture notes</td>
<td>Handouts during the class</td>
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<tr>
<td>Literature</td>
<td>Recommendations for text books will be covered in the class</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)</td>
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<tr>
<td>Taught competencies</td>
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</tbody>
</table>
| Domain A - Subject-specific Competencies | Concepts and Theories assessed  
Techniques and Technologies assessed |
| Domain B - Method-specific Competencies | Analytical Competencies assessed  
Decision-making not assessed  
Media and Digital Technologies not assessed  
Problem-solving assessed  
Project Management not assessed |
| Domain C - Social Competencies | Communication assessed  
Cooperation and Teamwork not assessed  
Customer Orientation not assessed  
Leadership and Responsibility not assessed  
Self-presentation and Social Influence not assessed  
Sensitivity to Diversity not assessed  
Negotiation not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility not assessed  
Creative Thinking not assessed  
Critical Thinking assessed  
Integrity and Work Ethics not assessed  
Self-awareness and Self-reflection not assessed  
Self-direction and Self-management not assessed |

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<tr>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Detting</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<tr>
<td>Objective</td>
<td>The course acquires advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<tr>
<td>Content</td>
<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies. The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be available.</td>
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</tbody>
</table>
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
<td>Techniques and Technologies</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td>Decision-making</td>
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<td>assessed</td>
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<tr>
<td>Media and Digital Technologies</td>
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<td>assessed</td>
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<tr>
<td>Problem-solving</td>
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<td>Customer Orientation</td>
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551-1619-00L Structural Biology

Does not take place this semester.

Abstract

The course consists of a series of research seminars on Structural Biology, Biochemistry and Biophysics, given by both scientists of the National Center of Competence in Research (NCCR) in Structural Biology and external speakers. Information on the individual seminars is provided on the following websites:

http://www.structuralbiology.uzh.ch/educ002.asp
http://www.biol.ethz.ch/dbiol-cal/index

Objective

The goal of this course is to provide doctoral and postdoctoral students with a broad overview on the most recent developments in biochemistry, structural biology and biophysics.

851-0180-00L Research Ethics

Number of participants limited to 40

Abstract

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective

Participants of the course Research Ethics will

• Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
• Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people's arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;
### I. Introduction to Moral Reasoning

1. Ethics - the basics
   1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
   2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
   3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

### II. Research Ethics - Internal responsibilities

1. Integrity in research and research misconduct
   1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
   2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
   3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

### III. Research Ethics – External responsibilities

1. Research involving human subjects
   1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
   2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
   3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

---

**Course material** (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

### Prerequisites / notice

What are the requirements?

First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):

1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!)
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…)
3. To have a basic understanding of Ethics and Research Ethics
4. To actively participate in discussions and exercises

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving

- **Domain B - Method-specific Competencies**
  - Communication
  - Cooperation and Teamwork
  - Critical Thinking

- **Domain C - Social Competencies**
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

- **Domain D - Personal Competencies**
  - Self-awareness and Self-reflection

---

**Abstract**

About 5 talks on applied statistics.

**Objective**

See how statistical methods are applied in practice.

**Content**

There will be about 5 talks on how statistical methods are applied in practice.

---

**Lecture notes**

Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

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### Taught competencies

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Competencies</th>
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<tbody>
<tr>
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<tr>
<td>Domain B - Method-specific Competencies</td>
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<td>Domain C - Social Competencies</td>
<td>Cooperation and Teamwork</td>
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<td>Domain D - Personal Competencies</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
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</tbody>
</table>

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**401-5640-00L ZüKoSt: Seminar on Applied Statistics**

**E- 0 credits 1K**


**Abstract**

This is a seminar on applied statistics.

**Objective**

See how statistical methods are applied in practice.

---

**401-0620-00L Statistical Consulting**

**E- 0 credits 0.1K**

- **M. Kalisch, L. Meier**

---

### Current Topics in Molecular and Cellular Neurobiology

**Abstract**
The course is a literature seminar or "journal club". Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.

**Objective**
The course introduces you to recent developments in the fields of cellular and molecular neurobiology. It also supports you to develop your skills in critically reading the scientific literature. You should be able to grasp what the authors wanted to learn i.e. their goals, why the authors chose the experimental approach they used, the strengths and weaknesses of the experiments and the data presented, and how the work fits into the wider literature in the field. You will present one paper yourself, which provides you with practice in public speaking.

**Content**
You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance.

**Lecture notes**
Presentations will be made available after the seminars.

**Prerequisites / notice**
You must attend at least 80% of the journal clubs, and give a presentation of your own. At the end of the semester there will be a 30 minute oral exam on the material presented during the semester. The grade will be based on the exam (45%), your presentation (45%), and a contribution based on your active participation in discussion of other presentations (10%).

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Lecturers</th>
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<td>Current Immunological Research in Zurich</td>
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<td>1K</td>
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<th>Credits</th>
<th>Semester</th>
<th>Lecturers</th>
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<td>551-1409-00L</td>
<td>RNA Biology Lecture Series II: Non-Coding RNAs: Biology and Therapeutics</td>
<td>W</td>
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<th>Lecturers</th>
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<tr>
<td>551-1407-00L</td>
<td>RNA Biology Lecture Series I: Transcription &amp; Processing &amp; Translation</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>F. Allain, N. Ban, U. Kutay, further lecturers</td>
</tr>
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</table>

**Abstract**
The Statistical Consulting service is open for all members of ETH, including students, and partly also to other persons.

**Objective**
Advice for analyzing data by statistical methods.

**Content**
Students and researchers can get advice for analyzing scientific data, often for a thesis. We highly recommend to contact the consulting service when planning a project, not only towards the end of analyzing the resulting data!

**Prerequisites / notice**
This is not a course, but a consulting service. There are no exams nor credits.

**Contact:** beratung@stat.math.ethz.ch. Tel. 044 632 2223. See also http://stat.ethz.ch/consulting

Requirements: Knowledge of the basic concepts of statistics is desirable.
The seminar covers the following topics:

- Choosing research topics based on recent literature published less than 1 year prior in a relevant journal.
- Understanding the impact of research on societal context and on their role as scientists.
- Developing skills in public speaking, presentation, and critical discussion.
- Applying practical tools to address specific challenges of inter- and transdisciplinary research.
- Discussing the significance of research in the broader context of biology, physiology, and medicine.

### Content

The seminar covers the following topics:

1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

### Literature

Literature will be made available to the participants.

  
  Available at (open access): http://www.ingentaconnect.com/content/oeckom/gaia/2017/00000026/00000001/art00011

Further, this collection of tools will be used:

https://naturalsciences.ch/topics/co-producing_knowledge

### Prerequisites / notice

- Participation in the course requires participants to be working on their own research project.
- Dates (Wednesdays, 8h15-12h00): 29 September, 27 October, 10 November, 24 November, 8 December

### Current Topics in Metabolism and Disease

**(551-1423-00L)**

**Abstract**

The course is a literature seminar or "journal club". Each Friday a student, or a member of the Stoffel Lab in the Institute of Molecular Health Sciences, will present a comprehensive presentation of a recent paper published in a top ranking international peer reviewed journal that relates to metabolism and disease.

**Objective**

The course introduces the students to recent developments in the fields of metabolism and disease. It also supports the development of analytical skills, including critical reading of scientific literature, being able to present and critically discuss scientific experiments, point out technical limitations, and placing recent discoveries in the broader context of biology, physiology and medicine. The student should be able to grasp what the authors wanted to learn i.e. their hypothesis and their goals, why the authors chose the experimental approach and methods used, the strengths and weaknesses of the experiments, the quality of the data presented, the conclusions drawn, and how the work fits into the wider literature in the field. Furthermore, the student should discuss alternative approaches and future experiments. Each student will present one paper during the course, which provides him/her with practice in public speaking.

**Content**

Each student will present at least once during the semester. The presentation includes an introduction to the field of the paper, a critical description of the main results, a summary of the main points and a discussion of their significance.

**Lecture notes**

Presentations will be made available after the seminars.

**Literature**

Students will be guided to choose their papers base on recent literature published less than 1 year prior in a relevant journal.

### Doctoral Thesis

**(551-0030-01L)**

**Abstract**

Doctoral Thesis

**Objective**

The course is a compulsory doctoral research seminar. Students will register for it.. The lecture takes place if a minimum of 12 students register for it.

### Doctoral Department Biology - Key for Type

<table>
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<th>Description</th>
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<tr>
<td>E-</td>
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<td>Dr</td>
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### Key for Hours

- **V**: Lecture
- **G**: Lecture with exercise
- **U**: Exercise
- **S**: Seminar
- **K**: Colloquium
- **P**: Practical/laboratory course
- **A**: Independent project
- **D**: Diploma thesis
- **R**: Revision course / private study

### ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Doctoral Department of Biosystems Science and Engineering


► Doctoral and Post-Doctoral Courses

<table>
<thead>
<tr>
<th>Number</th>
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<td>For doctoral students only.</td>
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<td>Master's students cannot receive credits for the seminar.</td>
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Abstract

This seminar will feature invited lectures about recent advances and developments in systems biology, including topics from biology, bioengineering, and computational biology.

Objective

To provide an overview of current systems biology research.

Content

The final list of topics will be available at https://www.bsse.ethz.ch/news-and-events/seminar-series.html

Course Catalogue of ETH Zurich

<table>
<thead>
<tr>
<th>Number</th>
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Doctoral Department of Biosystems Science and Engineering - Key for Type

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Key for Hours

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ECTS

European Credit Transfer and Accumulation System

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Doctoral Department of Chemistry and Applied Biosciences

Further information at: https://www.ethz.ch/en/doctorate.html

► Doctoral and Post-Doctoral Courses

►► Doctoral Studies in Inorganic Chemistry

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<td>D. Günther</td>
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<td>Abstract</td>
<td>Group seminar on elemental analysis and isotope ratio determinations using various plasma sources</td>
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<tr>
<td>Content</td>
<td>Developments in plasma mass spectrometry and alternative plasma sources</td>
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<td>529-0199-00L</td>
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529-0455-00L Laser for Micro- and Nanostructuring

<table>
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<tr>
<th>Type</th>
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<tr>
<td>W</td>
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<td>T. Lippert</td>
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</table>

Abstract
Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, will be discussed together with industrial applications, such as micro lithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Objective
Introduction to the fundamentals of lasers and their applications with an emphasis on micro- and nano-structuring. Several applications which are still in the research state, e.g. non-optical lithographies, will be discussed together with industrial applications, such as micro lithography and laser welding. Other aspects are the materials that are applied in these applications, e.g. photoresists, and their functioning.

Content
Introduction to lasers. Overview of micro- and nanotechnology, micro lithography, photoresists: classical types and new developments, laser cutting and welding, laser cleaning, laser ablation, polymer ablation: designed polymers, lasers and surfaces, laser spectroscopy, laser chemical vapor deposition, pulsed laser deposition (PLD), special materials by PLD, alternative structuring methods.

Lecture notes
The script (a copy of the slides) will be handed out during the first lecture.

Literature
FSRM, CD-ROM: An Introduction to the World of Microsystems, Neuchatel.

Autumn Semester 2021

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies not assessed
Decision-making not assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

►► Doctoral Studies in Organic Chemistry

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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0280-00L</td>
<td>Analytical Chemistry Seminar</td>
<td>E</td>
<td>0</td>
<td>1K</td>
<td>R. Zenobi</td>
</tr>
<tr>
<td>Abstract</td>
<td>Analytical Chemistry Seminar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Presentation and discussion of current research topics in analytical chemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Presentation and discussion of current research topics in analytical chemistry</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>529-0290-00L</td>
<td>Organic Chemistry (Seminar)</td>
<td>E</td>
<td>0</td>
<td>2S</td>
<td>E. M. Carreira, J. W. Bode, H. Wennemers, R. Zenobi</td>
</tr>
<tr>
<td>529-0299-00L</td>
<td>Organic Chemistry</td>
<td>E</td>
<td>0</td>
<td>1.5K</td>
<td>J. W. Bode, E. M. Carreira, P. Chen, H. Wennemers, R. Zenobi</td>
</tr>
<tr>
<td>529-1100-00L</td>
<td>Fragrance Chemistry</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Does not take place this semester.</td>
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</tbody>
</table>

The lecture provides a journey into the molecular world of scents from the chemical secrets behind Chanel N°5 to structure-odor relationships, industrial processes, and total synthesis of terpenoids. Each subunit is centered on one odorant family and highlights a certain class of chemical reactions, illustrated by prominent perfumery examples.
Objective
After completion of this lecture module the students know all the major perfumery materials of the important odor families with their academic and industrial syntheses, their olfactory properties, their usage, their historic perspective, and today's economic importance. The students can explain the significance of important building blocks and industrial transformations, and can estimate how attractive chemical processes are on large scale. They can retrosynthetically plan academic and industrial syntheses of fragrant compounds and terpenoids, and the acquired knowledge on structure-odor relationships enables them to predict and design new odors. The students can approximate the conformational space of odorants and especially macrocycles on the basis of simple rules, and know how olfactophore models are used. The students understand and can explain the molecular mechanism of smell, the biosynthesis of terpenes, and the basics of perfumery composition. The latter enables them to further their education in perfumery at specialized Universities such as the ISIPCA in Versailles; yet, the student also knows about the links of Fragrance Chemistry with Pharmaceutical Chemistry and the Specialty Chemicals business in general.

Literature

Prerequisites / notice
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

Doctoral Studies in Physical Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0490-00L</td>
<td>Special Topics in Theoretical Chemistry</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>M. Reiher</td>
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<tr>
<td>Abstract</td>
<td>Weekly seminar programme on special topics in theoretical and quantum chemistry. Talks delivered by PhD students and PostDocs as well as by external speakers.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>advanced course for PhD students and postdoctoral fellows</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>current research topics in theoretical chemistry</td>
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<td></td>
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<tr>
<td>Lecture notes</td>
<td>none</td>
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<tr>
<td>529-0460-00L</td>
<td>Computer Simulation</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>P. H. Hünenberger, S. Riniker</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Group meeting</td>
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<tr>
<td>529-0427-00L</td>
<td>Electron Spectroscopy</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>F. Merkt</td>
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<tr>
<td>Abstract</td>
<td>Group seminar on electronic spectroscopy, photoelectron spectroscopy, vacuum ultraviolet spectroscopy.</td>
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<tr>
<td>Content</td>
<td>Group seminar on electronic spectroscopy, photoelectron spectroscopy, vacuum ultraviolet spectroscopy.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Participation to this seminar must be discussed with the lecturer.</td>
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<tr>
<td>529-0479-00L</td>
<td>Theoretical Chemistry, Molecular Spectroscopy and Dynamics</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>F. Merkt, M. Reiher, J. Richardson, R. Signorell, H. J. Wörner</td>
</tr>
<tr>
<td>Abstract</td>
<td>Seminar on theoretical chemistry, molecular spectroscopy and dynamics.</td>
<td></td>
<td></td>
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<tr>
<td>529-0480-00L</td>
<td>Nuclear Magnetic Resonance Seminar</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>B. H. Meier</td>
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<tr>
<td>Abstract</td>
<td>Research seminar on current problems in nuclear magnetic resonance spectroscopy</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>529-0489-00L</td>
<td>Introduction to the Construction of Devices in Physical Chemistry</td>
<td>W</td>
<td>2</td>
<td>2P</td>
<td>B. H. Meier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Basic concepts of the construction of instrumentation in physical chemistry. Practical exercises in mechanical construction and electronic circuits.</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>Einführung in die elektronische Messtechnik, die Radiofrequenz- und Mikrowellentechnologie und in die Digitalelektronik.</td>
<td></td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Unterlagen in der ersten Stunde verteilt. Zugang mit Bewilligung des Dozenten</td>
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<td>529-0499-00L</td>
<td>Physical Chemistry</td>
<td>W</td>
<td>1</td>
<td>1K</td>
<td>M. Reiher</td>
</tr>
<tr>
<td>Abstract</td>
<td>Institute-Seminar covering current research Topics in Physical Chemistry</td>
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<tr>
<td>529-0491-00L</td>
<td>Seminar in Computational Chemistry C4</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>M. Reiher, J. Richardson</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research seminar with invited lecturers</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>529-0481-00L</td>
<td>Advanced High Resolution Molecular Spectroscopy</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>S. Albert</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course teaches advanced topics in molecular spectroscopy: techniques for analysing rotationally and rovibrationally resolved spectra will be discussed, the basics of FTIR spectroscopy will be reviewed, and the sources which may be used in high resolution infrared spectroscopy will be described. The fields in which high resolution infrared /THz spectroscopy is applied will also be reviewed.</td>
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<tr>
<td>Objective</td>
<td>The students will understand how to use the tools needed to analyze simple highly resolved spectra. They will become familiar with experimental techniques in high resolution molecular spectroscopy and will understand how molecular spectroscopy can be applied to solve problems with respect to atmospheric pollutants and the detection of molecules in interstellar space.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>The students will learn how to record rotationally and rovibrationally resolved spectra in the THz and IR frequency range. For that purpose state-of-the-art sources like synchrotrons, FELs and other THz sources will be discussed. In this context, the basics of Fourier transform infrared spectroscopy will also be reviewed. The analysis of such spectra with interactive programs will then be explained. Finally, applications of high resolution molecular spectroscopy in the field of atmospheric and interstellar chemistry will be discussed. The identification and the quantitative determination of atmospheric pollutants will be discussed in detail. In addition, the identification of interstellar molecules in the context of the origin of life will be reviewed. The question of the identification of the interstellar unidentified infrared bands and of the interstellar diffuse bands will also be addressed. Finally, high resolution molecular spectroscopy of chiral molecules in the context of molecular parity violation will be discussed</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Will be given in the lecture</td>
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<td></td>
<td></td>
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<tr>
<td>529-0470-00L</td>
<td>Literature Seminar in Theoretical Chemistry</td>
<td>Z</td>
<td>0</td>
<td>2S</td>
<td>M. Reiher</td>
</tr>
<tr>
<td>Abstract</td>
<td>In depth study of selected recent papers on theoretical chemistry</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Doktorats- und Mitarbeiterschulung</td>
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</table>

Doctoral Studies in Chemical and Bioengineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0960-00L</td>
<td>ICB Seminars on Chemical and Biochemical Engineering</td>
<td>W</td>
<td>1</td>
<td></td>
<td>P. Arosio</td>
</tr>
</tbody>
</table>

Abstract: The ICB seminar series covers the umbrella of diverse research activities encompassed within the institute, including catalysis, functional materials, polymer engineering, separations, microfluidics, process design, and systems engineering. This series was founded with the aim of promoting cross-disciplinary scientific discourse and interaction with other distinguished groups working worldwide.

Objective: Students are expected to attend all seminars in one academic year, and should register at the beginning of each seminar. Additionally, they must deliver a two-page written report at the end of the year describing the topics covered, main conclusions, and interrelationships between the different themes.

Content: The ICB seminar series covers the umbrella of diverse research activities encompassed within the institute, including catalysis, functional materials, polymer engineering, separations, microfluidics, process design, and systems engineering. This series was founded with the aim of promoting cross-disciplinary scientific discourse and interaction with other distinguished groups working worldwide, and is targeted at individuals who have made outstanding contributions within their fields. Each year, around 7 distinguished scientists and technologists will be invited to speak on topics of current interest in Chemical and Biochemical Engineering. PhD students are particularly encouraged to attend in order to broaden their perception and enrich their scientific horizons.

Doctoral Studies in Polymer Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0585-00L</td>
<td>Reactivity in Micelles and Vesicles</td>
<td>W</td>
<td>1</td>
<td></td>
<td>P. J. Walde</td>
</tr>
</tbody>
</table>

Abstract: Discussion of different aspects of the chemical reactivity in micelles and vesicles (liposomes) as polymeric compartments.

Objective: Deeper understanding of micelles and vesicles as self-organizing reaction compartments.

Content: With a few selected recent examples, properties of micelles and vesicles will be discussed with respect to applications as reaction compartments.

Doctoral Studies in Pharmaceutical Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-2000-00L</td>
<td>Seminar for Group Members  Does not take place this semester.</td>
<td>W</td>
<td>0</td>
<td></td>
<td>G. Schneider</td>
</tr>
</tbody>
</table>

Abstract: Weekly group seminar, in which members of the research team present and discuss the results of their projects and selected reports from the current scientific literature.

Objective: Participants learn to present scientific studies and discuss own results in greater context.

Content: State-of-the-art information on drug discovery and development by experts from academia and industry.

Objective: State-of-the-art information on drug discovery and development.

Content: Seminar series of the Institute of Pharmaceutical Sciences. Experts from academia and industry report on relevant topics.

Abstract: The lecture series takes place at the ETH Hönggerberg and covers a variety of major activities involved in drug discovery: selecting drug targets, technologies used in drug discovery, small, medium and large drugs, objectives of the medicinal chemist, assessing drug safety, principles of personalized medicine, designing clinical trials, how intellectual property is protected, as well as others.

Objective: The objective of the course is to gain a global understanding of most of the important phases in the discovery and development of modern synthetic and biological drugs, from the first activities to clinical trials. The lecture is intended for students that have an interest in the area and/or may consider a career working in drug discovery. This lecture course complements knowledge and experience gained in the research project performed by the PhD student.

Content: Thirteen two-hour lectures for life-science PhD students and students of the Pharmaceutical Sciences Master, given by experts from the ETH, UZH, USZ and the pharmaceutical industry.


Lecture notes: Scripts to be uploaded into ILIAS
### Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0195-00L</td>
<td>Scientific Information Retrieval &amp; Management in Life Sciences and Chemistry</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>O. Renn, L. Betschart, J. Dolenc</td>
</tr>
</tbody>
</table>

**Abstract**

Students learn how to effectively retrieve, critically judge, analyze and manage published scientific information – important skill sets in chemistry and life sciences where scientists need to deal with vast amounts of information. The course, using practical examples, also covers scientific writing, visualizations, science communication and state-of-the-art technologies such as text mining.

**Objective**

Students are made aware about the wide variety of information solutions that exist today for all kinds of research processes, get an independent understanding of how they are derived and learn how to critically judge their quality. They learn how scientific communication works today and on which concepts and principles it is based. They develop the ability to select appropriate, subject-specific databases or tools for a given specific scientific question based on a sound understanding on how a tool or database has been developed and maintained, thus building the personal capacity of doing research effectively and efficiently by integrating scientific information into the research process when needed. Students learn how to evaluate information solutions, to build suitable search strategies and to integrate them in their information workflows. Also, they learn how to effectively communicate their own scientific results using various distribution channels and to measure the impact of their outreach activities. Overall, they gain the ability to perform all steps of the research cycle in a time- and cost-efficient manner, from the research strategy up to writing a first paper and their Ph.D. thesis.

**Content**

The course has been primarily designed for Ph.D. students, also for the Life Science Zurich Graduate School, but is also open to Master students. In a series of 12 units, which always include practical examples (for some lectures a notebook is required), the use of scientific information is taught not in a database-centric view but corresponding to the steps through which scientific research is conducted – including the dissemination of scientific results. This is particularly interesting for students who are about to write-up their first paper or thesis. Students will learn about the different types of information resources and tools, get an insight into the numerous databases and tools that exists and how those are built and maintained, enabling them to critically judge the value and trustworthiness of an information resource. Additionally, they will learn how to communicate their own scientific results properly, using also additional measures that are reflected by alternative metrics.

The following topics are covered in twelve modules:
1. & 2. The world of scientific publishing: basics, publishing models
3. Searching and retrieving scientific information using search engines and literature databases
4. Searching and retrieving scientific information using subject-specific databases in chemistry and materials science
5. Searching and retrieving scientific information using subject-specific databases in life sciences
6. Tools for analyzing scientific information
7. Tools for managing scientific information and sharing knowledge, including pipelining tools
8. Patents
9. Text (literature) mining
10. Visualizing molecules for lab reports, presentations, posters, and publications
11. Scientific writing, good design & good scientific practice
12. Communicating & analyzing the impact of (your) science

**Lecture notes**

The slide deck and supplementary materials will be made available in the teaching document repository (ILIAS) after each lecture.

**Literature**

Additional literature and reference are provided in the course material.
### Doctoral and Post-Doctoral Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-0254-00L</td>
<td>Seminar Geochemistry and Petrology</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>O. Bachmann, M. Schönbächler, C. Chelle-Michou, M. W. Schmidt, D. Vance</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Seminar series with external and occasional internal speakers addressing current research topics. Changing programs announced via D-ERDW homepage (Veranstaltungskalender)</td>
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<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Presentations on isotope geochemistry, cosmochemistry, fluid processes, economic geology, petrology, mineralogy and experimental studies. Mostly international speakers provide students, department members and interested guests with insight into current research topics in these fields.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>Wöchentliches Seminar mit Fachvorträgen eingeladener oder interner Wissenschafter, vornehmlich zu Themen der Geochemie, Isotopengeochemie, Hydrothermalgeochemie, Lagerstättenbildung, Petrologie, Mineralogie und experimentelle Studien.</td>
</tr>
<tr>
<td>651-1617-00L</td>
<td>Geophysical Fluid Dynamics and Numerical Modelling</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>P. Tackley, T. Gerya</td>
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<tr>
<td>651-4931-00L</td>
<td>Seminar I: Heat and Mass Transfers in Magmatology</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>O. Bachmann, C. Chelle-Michou</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Does not take place this semester.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Heat and mass transfers from the mantle to the crust control many aspects of the differentiation of our planet, including (1) primitive melt chemistry, (2) layering of the crust, (3) type of volcanic eruption, (4) formation of mineral deposits. This year, we will focus on processes in crystal mushes (formation, crystallization, remobilization, degassing).</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>The class will focus mostly on 1) reading literature on topics of interests, 2) oral and written presentations of the papers, 3) exercises illustrating the topic, to allow students to work by themselves on some well-defined problems.</td>
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<tr>
<td>651-1180-00L</td>
<td>Research Seminar Structural Geology and Tectonics</td>
<td>Z</td>
<td>0</td>
<td>1S</td>
<td>W. Behr</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>A seminar series with invited speakers from both inside and outside the ETH.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The seminar series provides an opportunity to convey the latest research results to students and staff.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>Informal seminars with both internal and external speakers on current topics in Structural Geology, Tectonics and Rock Physics. The current program is available at: <a href="http://www.structuralgeology.ethz.ch/news-and-events/events-and-seminars.html">http://www.structuralgeology.ethz.ch/news-and-events/events-and-seminars.html</a></td>
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</table>

### Doctoral Department of Earth Sciences - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>Courses outside the curriculum</th>
</tr>
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<tbody>
<tr>
<td>W+</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>W</td>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>E-</td>
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</tbody>
</table>

### Key for Hours

<p>| | | |</p>
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<tr>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</table>

### ECTS

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Doctoral and Post-Doctoral Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>851-0587-01L</td>
<td>CIS PhD Colloquium</td>
<td>W</td>
<td>2</td>
<td>2K</td>
<td>University lecturers</td>
</tr>
<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: 615G932C</td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html">https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html</a></td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>In this internal colloquium doctoral students present their work after about 12 months of research.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>The aim of this colloquium is that the presenters receive feedback on their research at an important stage (a stage at which significant changes of direction, methodology, etc, may still be undertaken) in the PhD process.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>Presentation of doctoral research.</td>
</tr>
<tr>
<td></td>
<td>Prerequisites / notice</td>
<td></td>
<td></td>
<td></td>
<td>Distributed electronically.</td>
</tr>
<tr>
<td>851-0626-02L</td>
<td>PhD Colloquium in Development Economics</td>
<td>W</td>
<td>1</td>
<td>1K</td>
<td>I. Günther, K. Harttgen</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>PhD students working in empirical development economics will present their ongoing work, with a particular focus on the methods (to be used and challenges faced. Participants are expected to read the drafts/papers/presentations beforehand and give constructive feedback to the PhD student presenting.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
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<td></td>
<td>PhD students learn how to present and discuss their own research questions, methods, results and problems. PhD students get familiar with the challenges of empirical economics research in low income countries.</td>
</tr>
<tr>
<td></td>
<td>Prerequisites / notice</td>
<td></td>
<td></td>
<td></td>
<td>This is a two days course.</td>
</tr>
<tr>
<td>851-0735-10L</td>
<td>Business Law</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>P. Peyrot</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Particularly suitable for students of D-ITET, D-MAVT</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>A comprehensive script will be made available online on the moodle platform.</td>
</tr>
<tr>
<td>851-0735-09L</td>
<td>Workshop &amp; Lecture Series on the Law &amp; Economics</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Bechtold, H. Gersbach</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>This is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary research on intellectual property, innovation, antitrust, privacy &amp; technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. &amp; beyond.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
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<td></td>
<td>After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
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<td></td>
<td>The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>Papers discussed in the workshop and lecture series are posted in advance on the course web page.</td>
</tr>
<tr>
<td>851-0738-00L</td>
<td>Intellectual Property: Introduction</td>
<td>W*</td>
<td>2</td>
<td>2V</td>
<td>M. Schweizer</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td>The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.</td>
</tr>
</tbody>
</table>
The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Notice</th>
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</thead>
</table>
| The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace. | In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information. The lecture will acquaint participants with practical aspects of intellectual property and enable them to use this acquired knowledge in their future professional life. | - Topics covered during the lecture will include:  
  - The importance of innovation in industrialised countries  
  - An overview of the different forms of intellectual property  
  - The protection of technical inventions and how to safeguard their commercialisation  
  - Patents as a source of technical and business information  
  - Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups. |

Prerequisites / Notice

The seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay/report will be required (details to be specified in the introductory session of the course).

Prerequisites / Notice

Doctoral students in D-GESS can obtain 2 credit points for presenting their dissertation research plan.

851-0252-01L Human-Computer Interaction: Cognition and Usability

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Notice</th>
</tr>
</thead>
</table>
| This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects. | This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay/report will be required (details to be specified in the introductory session of the course). | - Topics covered during the lecture will include:  
  - The importance of innovation in industrialised countries  
  - An overview of the different forms of intellectual property  
  - The protection of technical inventions and how to safeguard their commercialisation  
  - Patents as a source of technical and business information  
  - Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups. |

Prerequisites / Notice

The colloquium invites presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan.

851-0252-04L Behavioral Studies Colloquium

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Notice</th>
</tr>
</thead>
</table>
| Participants are informed about recent and ongoing research in different branches of the behavioral sciences. Presenting doctoral students obtain feedback on their dissertation research plan. | This colloquium offers an opportunity to discuss recent and ongoing research and scientific ideas in the behavioral sciences, both at the micro- and macro-levels of cognitive, behavioral and social science. The colloquium features invited presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan. | - Topics covered during the lecture will include:  
  - The importance of innovation in industrialised countries  
  - An overview of the different forms of intellectual property  
  - The protection of technical inventions and how to safeguard their commercialisation  
  - Patents as a source of technical and business information  
  - Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups. |

Prerequisites / Notice

The colloquium features invited presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan.

851-0252-05L Research Seminar Cognitive Science

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Notice</th>
</tr>
</thead>
</table>
| The colloquium provides a forum for researchers and graduate students in cognitive science to present/discuss their ongoing projects as well as jointly discuss current publications in cognitive science and related fields. A subset of the sessions will include invited external visitors presenting their research. Participants of this colloquium are expected to be involved in active research group. | The seminar provides an opportunity to experience some of the methods in applied group projects. | - Topics covered during the lecture will include:  
  - The importance of innovation in industrialised countries  
  - An overview of the different forms of intellectual property  
  - The protection of technical inventions and how to safeguard their commercialisation  
  - Patents as a source of technical and business information  
  - Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups. |

Prerequisites / Notice

Doctoral students in D-GESS can obtain 2 credit points for presenting their dissertation research plan.

851-0585-41L Computational Social Science

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Notice</th>
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</thead>
</table>
| The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), (3) bridging between fundamental and applied work. | The colloquium invites presentations from internal and external researchers as well as presentations of doctoral students close to submitting their dissertation research plan. | - Topics covered during the lecture will include:  
  - The importance of innovation in industrialised countries  
  - An overview of the different forms of intellectual property  
  - The protection of technical inventions and how to safeguard their commercialisation  
  - Patents as a source of technical and business information  
  - Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups. |

Prerequisites / Notice

Doctoral students in D-GESS can obtain 2 credit points for presenting their dissertation research plan.
Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events.

They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.

**Background Knowledge Arabic World**

A reading list will be provided via moodle.ethz.ch at the beginning of the semester.

**Governing the Energy Transition**

This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socio-economic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.

- To gain knowledge on the role of policy and politics in energy transitions
- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions
- To gain an overview of the history of the transition of large technical systems

Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.

This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of policy and policy change in governing the energy transition, considering the role of political actors, institutions and policy feedback.

The grade will be determined by a final exam.

**Further literature will be recommended in the lectures.**

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**Literature**

- Manifesto of Computational Social Science
  https://link.springer.com/article/10.1140/epjst/e2012-01697-8

- Social Self-Organisation

- How simple rules determine pedestrian behaviour and crowd disasters
  https://www.pnas.org/content/108/17/6884.short

- Peer review and competition in the Art Exhibition Game
  https://www.pnas.org/content/113/30/8414.short

- Generalized network dismantling
  https://www.pnas.org/content/116/14/6554.short

- Computational Social Science: Obstacles and Opportunities
  https://science.sciencemag.org/content/369/6507/1060?rss%253D1=

- Bit by Bit: Social Research in the Digital Age
  https://www.amazon.co.uk/Bit-Social-Research-Digital-Age-ebook/dp/B072MPFXZ2/

**Prerequisites / notice**

This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science & Technology; MSc Environmental Sciences; MSc Management, Technology & Economics; MSc Science, Technology & Policy; ETH & UZH PhD programmes.
### Network Modeling

**Objective**
Teaching about epistemic contents relating to the Arabic world that constitute modern Arabs' self understanding and are relevant for adequate behavior in practically dealing with the Arabic world. What basic knowledge about ‘their’ culture are Arabs taught? What educational goals are pursued? What is the relationship they build with the West?

The topics that are discussed on the basis of a scientifically critical approach are concepts and understandings of history, the role of literature, sciences and religion, concepts of the West and relationship with the West, the role of education, understanding of culture and cultural refinement, current concepts and discourses relevant at the sociocultural level.

<table>
<thead>
<tr>
<th>851-0252-10L</th>
<th>Project in Behavioural Finance</th>
<th>W 3 credits</th>
<th>2S</th>
<th>S. Andraszewicz, C. Hölscher, A. C. Roberts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Particularly suitable for students of D-MTEC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Students will be able to develop hypotheses that relate to the structures and dynamics of (social) networks, and tests those by applying advanced statistical network methods such as exponential random graph models (ERGMs) and stochastic actor-oriented models (SAOMs). Students will be able to explain and compare various network models, and develop an understanding of how those can be fit to empirical data. This will enable students to independently address research questions from various social science fields.</td>
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</tbody>
</table>

### Interdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement

**Objective**
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

**Content**
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants' research projects more societally relevant

**Literature**
The following open access article builds a core element of the course:

Further, this collection of tools will be used

**Prerequisites / notice**
Participation in the course requires participants to be working on their own research project.

**Dates (Wednesdays, 8h15-12h00):**
- 29 September
- 27 October
- 10 November
- 24 November
- 8 December

### Project in Behavioural Finance

**Objective**
This course has four main goals:
1) To learn about the most important topics within Behavioural Finance
2) To learn how to conduct behavioural studies, design experiments, plan data collection and experimental tasks
3) To learn about causes of market crashes, factors that influence them, traders' behaviour before, during and after financial crises
4) To investigate a topic of interest, related to behaviour of traders during market crashes.

**Abstract**
In this seminar, students will study cognitive processes, behaviour and the underlying biological response to financial decisions. Research methods such as asset market experiments, lottery games, risk preference assessment, psychometrics, neuroimaging and psychophysiology of decision processes will be discussed. Financial bubbles and crashes will be the core interest.

<table>
<thead>
<tr>
<th>701-0015-00L</th>
<th>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</th>
<th>W 2 credits</th>
<th>2S</th>
<th>M. Stauffacher, C. E. Pohl, B. Vienni Baptista</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants' research projects more societally relevant.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>The seminar covers the following topics: (1) Theories and concepts of inter- and transdisciplinary research (2) The specific challenges of inter- and transdisciplinary research (3) Collaborating between different disciplines (4) Engaging with stakeholders (5) 10 steps to make participants' research projects more societally relevant Overall the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Literature will be made available to the participants.</td>
<td></td>
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</tr>
</tbody>
</table>

Further, this collection of tools will be used

**Prerequisites / notice**
Participation in the course requires participants to be working on their own research project.

**Dates (Wednesdays, 8h15-12h00):**
- 29 September
- 27 October
- 10 November
- 24 November
- 8 December

### Network Science

**Objective**
Emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

**Abstract**
Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks. Statistical and numerical methods have been developed to fit these models to empirical data. Emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

Particularly suitable for students of D-INFK and the MSc Data Science

**Prerequisites / notice**
Students are required to have basic knowledge in inferential statistics, such as regression models.

**Abstract**
Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks. Statistical and numerical methods have been developed to fit these models to empirical data.

**Objective**
Students will be able to develop hypotheses that relate to the structures and dynamics of (social) networks, and tests those by applying advanced statistical network methods such as exponential random graph models (ERGMs) and stochastic actor-oriented models (SAOMs). Students will be able to explain and compare various network models, and develop an understanding of how those can be fit to empirical data. This will enable students to independently address research questions from various social science fields.

**Course Goals:**
- To learn about the most important topics within Network Science
- To learn how to conduct behavioural studies, design experiments, plan data collection and experimental tasks
- To learn about causes of market crashes, factors that influence them, traders' behaviour before, during and after financial crises
- To investigate a topic of interest, related to behaviour of traders during market crashes.

**Prerequisites:**
- Participation in the course requires participants to be working on their own research project.
- Students are required to have basic knowledge in inferential statistics, such as regression models.

**Dates:**
- 19 September, if they can participate in the lecture.
- Active until 17 September.
- All students will be informed on 19 September, if they can participate in the lecture.
- The lecture takes place if a minimum of 12 students register for it.
The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DyNAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Lecture notes

Slides and lecture notes are distributed via the associated course moodle.

Literature


Prerequisites / notice

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Semester</th>
<th>Credits</th>
<th>V Semester</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0252-15L</td>
<td>Network Analysis</td>
<td>Winter</td>
<td>3</td>
<td>2</td>
<td>U. Brandes</td>
</tr>
<tr>
<td>851-0742-00L</td>
<td>Contract Design I</td>
<td>Winter</td>
<td>3</td>
<td>2</td>
<td>A. Stremitzer</td>
</tr>
</tbody>
</table>
Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design I will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvIdfG7ozq0). However, this course prioritizes applications of contract design. Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

Law & Tech

Number of participants limited to 30.

This course introduces students to legal, economic, and social perspectives on the increasing economic and social importance of technology. We focus particularly on the challenges to current law posed by the increasing rate of tech innovation and adoption generally and also by case-specific features of prominent near-future technologies.

The course is intended for a wide range of engineering students, from machine learning to bioengineering to human computer interaction, as well as for law students interested in acquiring a better understanding of state-of-the-art technology.

The course will combine both an overview of major areas of law that affect the regulation of technology and also guest lectures on the state-of-the art in a variety of important technologies, ranging from autonomous vehicles to fair artificial intelligence to consumer-facing DNA technologies.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.
The planned course outline is below

1. Overview of science, law, and technology
   a. Studies of law and technology
   b. Should science be regulated, and if so, how?
   c. Technology as a social problem

2. Designing technology for humans
   a. Attention fiduciaries and the digital environment
   b. Does technology weaponize known problems of bounded human rationality?
   c. Should technology be regulated as a psychotropic substance? An addictive substance?
   d. Can technology make life easier?
   e. Psychological effects of surveillance

3. Governing tech
   a. Can small governments regulate big tech?
   b. National and supranational legislation
   c. Enforcing the law with technology
   d. Can enforcement be baked into technology?

4. AI and fairness
   a. Discrimination
   b. Privacy
   c. Opacity
   d. AI and due process

5. Trade secret and technological litigation
   a. Trade secret is a long-standing tool for litigation but does it enjoy too much deference?
   b. Trade secrets and the rights of employees

6. Enforcement against tech
   a. Big tech and antitrust
   b. Consumer protection

7. The Digital Battlefield
   a. Technology for spying
   b. Spying on technology companies
   c. Race to be AI superpower
   d. Immigration policy

8. Contract law
   a. Smart contracts
   b. Modernizing contract law and practice
   c. Regulating cryptocurrencies

9. Tort law
   a. Applying existing tort law to new autonomous technologies
   b. Personhood and personal responsibility
   c. Victim entitlements

10. Self-driving cars and other autonomous robotics
    a. Legal regimes
    b. Diversity in morality judgements related to autonomous vehicles

11. Biometrics
    a. Widespread use of facial recognition
    b. Law enforcement
    c. Connecting biometrics to social data
    d. Solving crimes with biometrics

12. New Biology and Medicine
    a. Unregulated science (biohackers)
    b. Promising technology before it can be delivered
    c. Connecting medicine to social data
    d. Using technology to circumvent medical regulations

851-0101-86L Complex Social Systems: Modeling Agents, Learning, and Games

<table>
<thead>
<tr>
<th>Number of participants limited to 100.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerequisites: Basic programming skills, elementary probability and statistics.</td>
</tr>
<tr>
<td>Objective</td>
</tr>
<tr>
<td>The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically. The students should be able to implement simulation models and document their skills through a seminar thesis and finally give a short oral presentation.</td>
</tr>
<tr>
<td>Content</td>
</tr>
<tr>
<td>Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models. Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.</td>
</tr>
</tbody>
</table>
Analytical Competencies

M. Gath Morad
U. Brandes

Evaluating Architectural Design

Number of participants limited to 40

Abstract
Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

Objective
The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

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

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

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

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

851-0252-08L Evidence-Based Design: Methods and Tools For Evaluating Architectural Design

W 3 credits 2S M. Gath Morad, C. Hölscher, L. Narvaez Zertuche, C. Veddeler

851-0586-03L Applied Network Science: Social Media Networks

W 3 credits 1S U. Brandes

851-0253-07L Consciousness Studies

W 2 credits 2V K. Stocker

Further literature will be recommended in the lectures.

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Prerequisites / notice

Prerequisites:
- Knowledge of basic architectural design concepts
- Understanding of basic principles of space syntax
- Basic programming skills in Python or R

Further literature will be recommended in the lectures.

The study of consciousness involves scholars from diverse fields, such as psychology, neuroscience, cognitive science, philosophy, linguistics, computer science, medicine, religious studies, anthropology, as well as literature and art studies. While the study of consciousness is presented mainly from the point of view of psychology in this course, additional interdisciplinary viewpoints are also integrated.

Psychological consciousness studies involve research on levels and states of consciousness. Psychologically researched levels of consciousness are the conscious, preconscious, unconscious/subconscious, and nonconscious levels of mental processing. Psychological research on states of consciousness – which is the main focus of this course – takes waking consciousness as the most common state (ordinary state of consciousness, OSC), using it as a baseline against which altered states of consciousness (ASCs) are compared. Some of the most prominently or promising researched ASCs in psychology will be introduced in this course and include sleeping/dreaming, hypnosis, meditation, sensory deprivation (e.g., floating tank), rhythm-induced trance, as well as ASCs induced by psychoactive drugs (classic psychedelics, dissociative anesthetics, empathogens). Furthermore, it will also be shown how a growing number of health and clinical studies investigate the therapeutic potential of being temporarily in an ASC. Finally, in this course, two mental phenomena that are also highly relevant for the scientific mind – insight and flow – are also introduced from a consciousness-studies perspective.

Building a Robot Judge: Data Science for Decision-Making
Particularly suitable for students of D-INFK, D-ITET, D-MTEC

This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

Content
Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a seminar paper, students (individually or in groups) will conceive and implement an applied data-science research project.

Building a Robot Judge: Data Science for Decision-Making (Course Project)
This is the optional course project for "Building a Robot Judge: Data Science for the Law."

Please register only if attending the lecture course or with consent of the instructor.

Abstract
Some programming experience in Python is required, and some experience with text mining is highly recommended.

Objective
In a semester paper, students (individually or in groups) will conceive and implement their own research project applying natural language tools to legal texts. Some programming experience in Python is required, and some experience with NLP is highly recommended.

Content
Students will investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models.

We will use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a seminar paper, students (individually or in groups) will conceive and implement an applied data-science research project.

Mind and Brain
In the last 2500 years, the mind-brain relationship has been articulated in various ways. In these lectures, I will explore the scientific and philosophical aspects of this relationship in the context of relevant cultural, historical and technological processes, with a focus on the modern neuosciences, but I will also discuss works of art and literature.
While being the universal constant which is common to every human being in history, the body is also culturally and historically specific. In G. Sissa's "Négritude" to the "Ateliers de la pensee" (2016), we will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities. We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities; this from the Négritude movement (1930s) to the Dakar Thought Workshops ("Ateliers de la pensee", 2016). We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

The course is structured thematically, adopts a multidisciplinary approach, and uses academic texts as well as concrete examples. It intends to a) enable STEM students to develop new perspectives on their core subjects by bringing them in dialogue with the themes dealt with and by raising ethical questions; b) familiarise students in general with major topics in the field of the recent scholarship on the body and make them mindful of the multiple ways in which understanding the body and its relationship with culture and power can help think critically of the present we live in.
This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

Objective
This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

Content
Once upon a time there was natural law, the foundation of sexual relations between two people of different genders, in order to procreate. However, the long-term history shows us a great variety of erotic cultures, from ancient Greece to the Roman world and then to Christian and multicultural Europe. This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

851-0101-72L The Modern City and Cultural Criticism. The “Knowledge of Life” in Reform Movements 1880-1933

Abstract
Rapid industrialisation, urbanisation and the unique sociopolitical conditions of 19th century Germany led, from 1860 onwards, to radical cultural criticism and calls for reform by parts of the bourgeoisie and youth.

Objective
The lecture is part of the “Science in Perspective” course programme: students will learn about the precursors of today’s calls for reform and alternative concepts which propagated the “back-to-nature” lifestyle around the 1900s.

Content
The rapid industrialisation, mechanisation and urbanisation of 19th century Europe gave rise to a whole new set of challenges and problems in cities. From 1860 onwards, the unique sociopolitical conditions in Germany resulted in anti-urban and cultural criticism by parts of the bourgeoisie and academic youth, culminating in the idea that the fanatical belief in progress would end in disaster. Consequently, a wide array of reform movements sprang up, focusing on medical hygiene and sociopolitical, ideological, religious and spiritual concepts, which were intended to heal the mind and body. These movements were a wholly German and Swiss phenomenon and summarised under the term “Lebensreform” which also encompassed naturopathy, dress reforms, naturism, health food and vegetarianism, youth and women’s movements, sexual liberation and intentional communities, organic farming, land reform, cooperative/free economy/garden city movements, nature conservation and homeland protection, progressive education and country boarding school movement, art education and Dalcroze eurythmics, expressive dance, theatre reforms, regional literature and art, anthroposophy, the emergence of Germanic-German Christian religious communities, religious socialism and the Jewish renaissance.

This movement was clearly politically diverse, and attracted all manner of advocates, for example, those with social anarchist, jingoistic or anti-Semitic beliefs. What made them kindred spirits was their rather negative experience of modernisation: their fantasies about the era of reason were confirmed that existing interpretations of the human existence were obsolete. Amongst the fantasies was, as described by Gert Mattenklott, the idea of a dramatic shift in current thinking and the creation of a new world, the emergence of a new mankind that embodied the characteristics of youth, and a new community. Strong dichotomies like light and darkness, hot and cold, the fears of dehumanisation and a propensity for vegetarianism were also typical of life reforms.

The lecture is part of the “Science in Perspective” course programme: students will learn about the precursors of today’s calls for reform and alternative concepts which propagated the “back-to-nature” lifestyle around the 1900s. Some of the key concepts used then are unknown today or have been disavowed due to exploitation by the totalitarian regimes of the 20th century. Nevertheless, some of the original topics and objectives have once again become contemporary topics of discussion in the debate about the future of society, the whole of mankind and the planet. Historization of present-day concepts is the condition on which plans for a possible future can be compared with previous attempts and experiences, and to identify alternatives and potential impulses, and provide objective evidence for debate.

851-0536-00L Technology and the Environment – On Course for OpIllopion?

Abstract
Technology has been both the cause and the solution of many environmental problems. Motor vehicle emissions contribute to climate change. Apps are supposed to help us minimizing our CO2 footprint. This course examines which politics, social relations, economic interests, environmental changes, and forms of engineering have conditioned which types and consequences of technology in modern history.

Objective
Students will discuss primary and secondary sources about the relationship between technology and the environment since the nineteenth century. They will learn to analyze argumentative strategies, divergent perspectives, and consequences and to write precisely and trenchantly about technology and the environment in society.

851-0742-01L Contract Design II

Abstract
Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by working with a client.

Objective
Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

Prerequisites / notice
To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

851-0551-1BL Colloquium for Master and PhD Students History of Technology (HS 2021)

Abstract
Colloquium for master and doctoral students preparing a thesis in the history of technology.

Objective
Goals: to identify, discuss, and resolve methodological problems that emerge while elaborating a master or doctoral thesis.

Anmeldung bei Rachele Delucchi (rachele.delucchi@history.gess.ethz.ch). Siehe fürs Programm auch: www.tg.ethz.ch

851-0535-10L Yemen: A Failed State?

Abstract
Is Yemen a failed state? The Yemen Republic is the result of the unification in 1990 of two former states: The Yemen Arab Republic (North Yemen) and the People's Democratic Republic of Yemen (South Yemen). The country's history and its former units have been marred with civil wars, poverty and epidemic corruption.
### Objective
1. Examine the concept of failed state within the International relations literature.
2. Take a closer look at Yemen(s) political history(ies), its/their political and social structures, and power dynamics.
3. Introduce the concept of the 'cunning state' and its exploitation of the discourse of failed state

### Content
This seminar looks at the concept of failed states and how useful it can be in describing the situation in a country like Yemen. It will also take a closer look at Yemen(s) political history(ies) and its/their political and social structures. Students are expected to write a paper and make a presentation.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Semester</th>
<th>Credits</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
<th>Language of performance assessment</th>
<th>Language of instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0062-00L</td>
<td>Doctoral Seminar «History of Knowledge» (University of Zurich)</td>
<td>W</td>
<td>2</td>
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<td></td>
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<td>English</td>
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<td>851-0125-65L</td>
<td>A Sampler of Histories and Philosophies of Mathematics</td>
<td>W</td>
<td>2</td>
<td>accessed</td>
<td></td>
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<tr>
<td>851-0125-76L</td>
<td>Critiques of Scientific Objectivity</td>
<td>W</td>
<td>2</td>
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<tr>
<td>851-0197-00L</td>
<td>Medieval and Early Modern Science and Philosophy</td>
<td>W</td>
<td>3</td>
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<td>851-0255-00L</td>
<td>Introduction to Methods in Learning Sciences II</td>
<td>W</td>
<td>2</td>
<td>accessed</td>
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<td>851-0256-00L</td>
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<td>W</td>
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<td>English</td>
<td>German and English</td>
</tr>
</tbody>
</table>
The summer school is aimed at doctoral students who, in their historical research projects, investigate knowledge in social contexts. This colloquium offers an opportunity for students to present and discuss their ongoing projects broadly related to the science of learning.

The Unconditionality of Knowledge: Faust in
European Literature

His unconditional desire for knowledge made "Faust" the symbolic figure of the modern period. Since the Renaissance, a rich Faust-literature, ranging from Marlowe, Goethe, and up to Thomas Mann, has portrayed the highly conflicted emancipation of knowledge from theology as well as the self-assertion of a modern knowledge of nature and the human being.

Learning objectives: Faust is one of the most dazzling figures in European literature and cultural history. A pact with the devil, magic, sexual desire, power and knowledge, these are the great taboos of the medieval world, which, in 1500, the graduated theologian set out to dismantle. Through this demonstrative gesture of hubris, he became the much-disputed hero of the modern period. Since the "Historia von Johann Fausten" (1587), the wide range of Faust-literature also depicts the highly conflicted emancipation from theological knowledge in favor of an unconditional knowledge of nature and the human being that hides itself behind disciplines such as medicine, astrology and magic. Faust was thereby not only transformed into the epitome of the fortuneteller, he also became the cipher for the risky undertaking of modern knowledge as such, to which he then spectacularly fell victim in an experiment. Consequently, the course's treatment of this subject matter in the literature since the early modern period will center on the question of knowledge as it is negotiated through the Faust-figure. Initially, we shall take a look at examples from the early modern period (apart from the Faust-book from 1587, among others the drama version by Christopher Marlowe, 1589). Finally, we shall move on to new editions around 1800, which highlight the modernity of this norm-breaking and boundary-breaking knowledge paradigm (among others Goethe's Faust). Finally, we shall discuss Faust-figures of the 20th century, such as Friedrich Murnau's Faust movie (1926), Thomas Mann's novel, "Doktor Faustus", written in exile in 1947, or Klaus Mann's "Mephisto" (1936).

Knowledge and Practice in Philosophy of War Does not take place this semester.

In the seminar we read classical texts from the field of 'philosophy of war'. Due to today's technological advancements and ecological problems, we will also discuss contemporary conceptions of war such as lethal autonomous weapons and climate change. Important questions that arise are: Is the concept of war applicable to human society? Is there a difference between politics and nature? Scientific knowledge is often provisional; it is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of scientific knowledge. This is shown by the Corona pandemic, but not only by it. It is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of scientific knowledge. This is shown by the Corona pandemic, but not only by it. In any case, what can, what should, do «laymen» want to know and understand from scientific findings? Scientific knowledge is often provisional; it is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of scientific knowledge. This is shown by the Corona pandemic, but not only by it. How can science journalism, how can scientists deal with this problem? Do the natural sciences, medicine and technology differ from the humanities and social sciences in terms of comprehensibility and public awareness? These questions will be explored on some excursions into recent and also older media, scientific and cultural history.

Histories of Knowledge in Society (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Knowledge is not only an element within scientific institutions and disciplines. In the form of public debates, medical and technical applications and administrative measures it is also part of the social space. The summer school is aimed at doctoral students who, in their historical research projects, investigate knowledge in social contexts. In exchange with Swiss and international professors from the field of the history of knowledge and in relation to the participants’ research projects, methods will be developed to analyze the forms, functions and circulation of knowledge in social dimensions.

Writing and Publishing Reviews (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Writing reviews is part of academic publishing. Crucial ingredient is the evaluation of the book within the relevant research field.
PhD students will have an opportunity to improve their presentation skills and obtain an important chance to receive feedback both from experts and peers. Hence, they are encouraged to present their current work in progress. The colloquium is designed for advanced and graduate students/special-students who are enrolled in a master program or in a degree program of the University of Zurich. The questions of the slots are reserved for presentations by invited external scholars. The objectives of the colloquium are to discuss methodological, theoretical and systematic complex issues of the presented topics. Lectures may be held either in English or German. Students receive 2 credit points for submitting a brief, written commentary on one of the presented topics (approx. 5 pages). For registration please write to: zgw-dp@ethz.ch

**Research Colloquium Philosophy for Master Students**

*Objective*

The workshop introduces the requirements of reviews in the humanities, especially in the history of knowledge and related fields (history of science, history of medicine, history of knowledge, social history, gender history, legal history etc.). The participants will learn how to publish a review in a scientific journal.

*Prerequisites / notice*

For registration please write to: zgw-dp@ethz.ch

**Research Colloquium Philosophy for Master Students**

*Objective*

Ph.D. students, post docs, members of staff, and senior colleagues from other philosophy departments will report on their work in progress. Furthermore, promising new philosophical articles and parts of new philosophical books will be studied.

*Abstract*

Ideas and arguments dealing with systematic problems especially in epistemology, ethics, political philosophy, and the philosophy of mind will be scrutinized and elaborated.

**Research Colloquium, Extra-European History and Global History (HS 2021)**

*Objective*

The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

*Prerequisites / notice*

Information about dates and program can be found on the institute’s website - [http://www.wiss.ethz.ch/en/teaching/](http://www.wiss.ethz.ch/en/teaching/)

**Research Colloquium Science Studies (HS 2021)**

*Objective*

This colloquium is devoted to the introduction into the theory and practice of scientific work. The schedule can be found on the institute’s website - [http://www.wiss.ethz.ch/en/teaching/](http://www.wiss.ethz.ch/en/teaching/)

*Abstract*

This colloquium is devoted to the introduction into the theory and practice of scientific work.

**Advanced Colloquium in Literary Studies (HS 2021)**

*Objective*

The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

*Abstract*

The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

**Basic Problems of Environmental Ethics**

*Objective*

Participants should become familiar with basic approaches to central problems in environmental ethics.

*Abstract*

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies? Another focus will be to clarify the concept of "climate justice".

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

**Science in Society**

*Objective*

Whose voice should count how much? On the authority of the sciences in democracy.

*Abstract*

Not a few members of the elites argue that important issues in democracy like policies against climate change, free trade agreements, urban planning are too complicate for the people. Experts should have a stronger say in politics. Less democracy = more rationality? The course should give an answer to this question.

**Philosophy of Psychiatry**

*Objective*

The objective of this course is to offer historical context and philosophical reflection on mental disorders and psychiatric practices.
Content Psychiatry is one of the most controversial areas of medicine. All medicine involves some negotiation about assumptions and values, at the professional-patient and societal levels. For example, its clinical categories are imposed on the subject, who is interpreted according to a given physiological (but also political and economical) framework. However, because psychiatry is primarily concerned with beliefs, moods, relationships, and behaviors, this negotiation actually constitutes the bulk of its clinical endeavors. This course offers an overview of some representative topics in philosophy of psychiatry. Some of these are the character of mental disorders, the takeover of the mind by the medical model, the demarcation of normal and abnormal behavior, the influence of culture in the understanding of mental disorders, a critical understanding of the DSM and its evolution, and the interplay between psychiatry and legal responsibility.

851-0624-00L ETH4D PhD Seminar: Research for Development ■ W 1 credit 1K I. Günther, A. Rom, E. Tilley Number of participants limited to 15.

Abstract Doctoral candidates from all ETH departments, whose research is related to global sustainable development issues, and conducting research in low- or middle-income countries are invited to give a presentation about their on-going work and discuss their doctoral project with a diverse group of researchers.

Objective Doctoral students are able to present their doctoral project to an interdisciplinary audience and to respond to questions within a wider global sustainable development context.

851-0367-00L Introduction to EEG Data Analysis W 2 credits 2S H. Poikonen

Abstract We learn in a hands-on manner the basics of EEG data analysis with MATLAB and are introduced to the origin of EEG signal in the brain to understand how the electrical properties of the brain and skull may influence the signal. We learn the core factors of EEG study design and data analysis to be able to interpret the EEG results critically. Basic programming skills are required.

Objective The objectives of the course are to learn the basics of EEG data analysis, basics of the critical interpretation of the results and to screen for the most common errors during the EEG data analysis.

Content On the course, we go through step by step the basics of EEG data processing from raw data to preparation of the data for statistical analyses. The steps include filtering and re-referencing the data, removing eye-movement artefacts with Independent Component Analysis, setting time stamps and epoching the data. Participants also have a possibility to work with their own EEG data.

851-0008-00L Ban on Alcohol and Science: A Global History of Prohibition 1918–1939 W 3 credits 2S E. Biçer-Deveci

Abstract The reconstruction of the development of prohibitionist regimes helps to understand the process of national institution formations, for example health services. Participants analyze interactions between science, international relations and change of social political context in the process of knowledge production and in the definition of daily life norms on drinking habits.

Objective The objectives of the course are to learn the basics of EEG data analysis, basics of the critical interpretation of the results and to screen for the most common errors during the EEG data analysis.

Content On the course, we go through step by step the basics of EEG data processing from raw data to preparation of the data for statistical analyses. The steps include filtering and re-referencing the data, removing eye-movement artefacts with Independent Component Analysis, setting time stamps and epoching the data. Participants also have a possibility to work with their own EEG data.

851-0651-00L Communicating Science for Global Development ■ W 0.5 credits 1S A. Rom

Abstract The seminar deals with an overview of anti-alcohol campaigns since late 19th century. The focus is on prohibition in the interwar period in different regions. The role of scientific experts in the emergence of prohibition will be discussed from a global historical perspective.

Objective The objectives of the course are to learn the basics of EEG data analysis, basics of the critical interpretation of the results and to screen for the most common errors during the EEG data analysis.

Content On the course, we go through step by step the basics of EEG data processing from raw data to preparation of the data for statistical analyses. The steps include filtering and re-referencing the data, removing eye-movement artefacts with Independent Component Analysis, setting time stamps and epoching the data. Participants also have a possibility to work with their own EEG data.

**Doctoral Department of Humanities, Social and Political Sciences - Key for Type**

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

**Key for Hours**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>P</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
</tr>
</tbody>
</table>

**ECTS** European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Health Sciences and Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Abstract**
Current topics in translational medicine presented by speakers from academia and industry.

**Objective**
Getting insight into actual areas and problems of translational medicine.

**Content**
Timely and concise presentations of postgraduate students, post-docs, senior scientists, professors, as well as external guests from both academic and industry will present topics of their interest related to translational medicine.

**Prerequisites / notice**
No compulsory prerequisites, but student should have basic knowledge about biomedical research.

<table>
<thead>
<tr>
<th>Number</th>
<th>ETHeart Joint Scientific Colloquium (Autumn Semester)</th>
<th>W</th>
<th>1</th>
<th>1K</th>
<th>N. Cesarovic, V. Falk, H. Rodriguez Cetina Biefer</th>
</tr>
</thead>
</table>

**Abstract**
Lectures, presentations and discussions on chosen topics in biologics, (bio-) materials, devices, sensors, robotics and data science and their relevance for cardiovascular medicine.

**Objective**
Deeper, mutual understanding of current medical challenges and technical solutions in cardiovascular medicine.

**Content**
Timely and didactically structured presentations of postgraduate students, post-docs, senior scientists and professorson topics from Zurich Heart / ETHeart projects, followed by lectures on chosen topics of cardiovascular medicine and research given by leading international clinical scientists in the field.

**Prerequisites / notice**
No compulsory prerequisites, but students should have basic knowledge about cardiovascular system, physiology and biomedical research.

<table>
<thead>
<tr>
<th>Number</th>
<th>Introductory Course in Neuroscience I (University of Zurich)</th>
<th>W</th>
<th>2</th>
<th>2V</th>
<th>University lecturers</th>
</tr>
</thead>
</table>

**Abstract**
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: SPV0Y005

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

**Objective**
The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

**Content**
1) Human Neuroanatomy I,II.
2) Comparative Neuroanatomy.
3) Building a central nervous system I,II.
4) Synapses I,II.
5) Glia and more.
6) Excitability.
7) Circuits underlying Emotion.
8) Visual System.
9) Auditory & Vestibular System.
10) Somatosensory and Motor Systems.

**Prerequisites / notice**
For doctoral students of the Neuroscience Center Zurich (ZNZ).

<table>
<thead>
<tr>
<th>Number</th>
<th>Translation of Basic Research Findings from Genetics and Molecular Mechanisms of Aging</th>
<th>W</th>
<th>3</th>
<th>2V</th>
<th>to be announced</th>
</tr>
</thead>
</table>

**Abstract**
Recently, several start-up companies are aiming to translate basic molecular findings into new drugs/therapeutic interventions to slow aging or post-pone age-related diseases (e.g., Google founded Calico or Craig Venter's Human Longevity, Inc.). This course will teach students the basic skill sets to formulate their own ideas, design experiments to test them and explains the next steps to translate aging or postpone age-dependent diseases.

**Objective**
1. Evaluate the current problem of our aging population, the impact of age-dependent diseases and current strategies to prevent these problems.
2. Analyse/compare current molecular/genetic strategies that address these aging problems.
3. Analyse case studies about biotech companies in the aging sector. Apply the scientific methods to formulate basic research questions to address these problems.
4. Generate own hypotheses (educated guess/idea), design experiments to test them, and map out the next steps to translate them.

**Content**
Overview of aging and age-related diseases. Key discoveries in molecular biology of aging. Case studies of biotech companies addressing age-related complications. Brief introduction from bench to bedside with focus on start-up companies.

**Prerequisites / notice**
No compulsory prerequisites, but student should have basic knowledge about genetics and molecular biology.

<table>
<thead>
<tr>
<th>Number</th>
<th>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</th>
<th>W</th>
<th>2</th>
<th>2S</th>
<th>M. Stauffacher, C. E. Pohl, B. Vienni Baptista</th>
</tr>
</thead>
</table>

**Number**
Priority is given to PhD students D-USYS.
All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture. The lecture takes place if a minimum of 12 students register for it.

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
1. Theories and concepts of inter- and transdisciplinary research
2. The specific challenges of inter- and transdisciplinary research
3. Collaborating between different disciplines
4. Engaging with stakeholders
5. 10 steps to make participants’ research projects more societally relevant
Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature
Literature will be made available to the participants.
The following open access article builds a core element of the course:
available at (open access): http://www.ingentaconnect.com/content/oekom/gaia/2017/00000026/00000001/art00011
Further, this collection of tools will be used
https://naturalsciences.ch/topics/co-producing_knowledge

Food Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-0005-00L</td>
<td>Colloquium in Food and Nutrition Science</td>
<td>E-</td>
<td>1 credit</td>
<td>2K</td>
<td>S. J. Sturla</td>
</tr>
</tbody>
</table>

Abstract
Participation in weekly seminars on a variety of topics including Food Microbiology, Food Toxicology, Food Biochemistry, Food Processing, Consumer Behavior, Food Technology, and Food Materials and Technology, and oral presentation of a selected published study in one of these areas inspired by participation in the seminars.

Objective
The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the semester presentations.

Course Catalogue of ETH Zurich

Doctoral Department of Health Sciences and Technology - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended Z</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits Dr</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits O</td>
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</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Type</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture P</td>
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<td>G</td>
<td>lecture with exercise A</td>
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<tr>
<td>U</td>
<td>exercise D</td>
</tr>
<tr>
<td>S</td>
<td>seminar R</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Doctoral Department of Computer Science

► Doctoral and Post-Doctoral Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>264-5812-00L</td>
<td>Research Topics in Software Engineering</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Milligan</td>
</tr>
<tr>
<td>264-5812-00L</td>
<td>Writing for Publication in Computer Science (WPCS)</td>
<td>Z</td>
<td>2</td>
<td>1G</td>
<td>S. Milligan</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 15.</td>
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<tr>
<td></td>
<td>Only for D-INFK doctoral students.</td>
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<tr>
<td></td>
<td>This short course is designed to help junior researchers in Computer Science develop the skills needed to write their first research articles.</td>
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<tr>
<td>Abstract</td>
<td>Writing for Publication in Computer Science is a short course (5 x 4-lesson workshops) designed to help doctoral students develop the skills needed to write their first research articles. The course deals with topics such as:</td>
<td></td>
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<tr>
<td>Objective</td>
<td>- understanding the needs of different target readerships,</td>
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<tr>
<td></td>
<td>- managing the writing process efficiently,</td>
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<tr>
<td></td>
<td>- structuring texts effectively,</td>
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<tr>
<td></td>
<td>- producing logical flow in sentences and paragraphs,</td>
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<tr>
<td></td>
<td>- editing texts before submission,</td>
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<tr>
<td></td>
<td>- revising texts in response to colleagues' feedback and reviewers' comments.</td>
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</tr>
<tr>
<td>Content</td>
<td>Participants will be expected to produce a number of short texts (e.g., draft of a conference abstract) as homework assignments; they will receive individual feedback on these texts during the course. Wherever feasible, elements of participants' future conference/journal articles can be developed as assignments within the course, so it is likely to be particularly useful for those who have i) their data and are about to begin the writing process, or ii) an MSc thesis they would like to convert for publication.</td>
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</tbody>
</table>

252-4202-00L | Seminar in Theoretical Computer Science                            | W    | 2    | 2S    | E. Welzl, B. Gärtner, M. Ghaffari, M. Hofmann, J. Lengler, A. Steger, D. Steurer, B. Sudakov |

252-1425-00L | Geometry: Combinatorics and Algorithms                            | W    | 8    | 3V+2U+2A | B. Gärtner, E. Welzl, M. Hofmann, M. Wettstein |
|             | Prerequisites / notice                                            |      |      |       |                                                |
|             | This seminar takes place as part of the joint research seminar of several theory groups. Intended participation is for students with excellent performance only. Formal restriction is: prior successful participation in a master level seminar in theoretical computer science. |      |      |       |                                                |
| Abstract    | Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?) |      |      |       |                                                |
| Objective   | The goal is to make students familiar with fundamental concepts, results and techniques in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project. |      |      |       |                                                |
| Content     | Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in Rd, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations. |      |      |       |                                                |

263-2100-00L | Research Topics in Software Engineering                          | W    | 2    | 2S    | P. Müller, M. Püschel |
|             | Number of participants limited to 22.                             |      |      |       |                                                |
|             | The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar. |      |      |       |                                                |
| Abstract    | This seminar is an opportunity to become familiar with current research in software engineering and more generally with the methods and challenges of scientific research. |      |      |       |                                                |
| Objective   | Each student will be asked to study some papers from the recent software engineering literature and review them. This is an exercise in critical review and analysis. Active participation is required (a presentation of a paper as well as participation in discussions). |      |      |       |                                                |
| Content     | The aim of this seminar is to introduce students to recent research results in the area of programming languages and software engineering. To accomplish that, students will study and present research papers in the area as well as participate in paper discussions. The papers will span topics in both theory and practice, including papers on program verification, program analysis, testing, programming language design, and development tools. A particular focus will be on domain-specific languages. |      |      |       |                                                |
| Literature  | The publications to be presented will be announced on the seminar home page at least one week before the first session. |      |      |       |                                                |
| Prerequisites / notice | Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH. |      |      |       |                                                |
|             | Outlook: In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area. |      |      |       |                                                |

|             | Only for Computer Science Ph.D. students.                         |      |      |       |                                                |
|             | This doctoral seminar is intended for PhD students affiliated with the Institute for Machine Learning. Other PhD students who work on machine learning projects or related topics need approval by at least one of the organizers to register for the seminar. |      |      |       |                                                |
Abstract
An essential aspect of any research project is dissemination of the findings arising from the study. Here we focus on oral communication, which includes: appropriate selection of material, preparation of the visual aids (slides and/or posters), and presentation skills.

Objective
The seminar participants should learn how to prepare and deliver scientific talks as well as to deal with technical questions. Participants are also expected to actively contribute to discussions during presentations by others, thus learning and practicing critical thinking skills.

Prerequisites / notice
This doctoral seminar of the Machine Learning Laboratory of ETH is intended for PhD students who work on a machine learning project, i.e., for the PhD students of the ML lab.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor(s)</th>
</tr>
</thead>
</table>

Abstract
In this doctoral seminar, current research at the Institute for Visual Computing will be presented and discussed. The goal is to learn about current research projects at our institute, to strengthen our expertise in the field, to provide a platform where research challenges can be presented and discussed, and to also practice scientific presentations.

Objective
In this doctoral seminar, current research at the Institute for Visual Computing will be presented and discussed. The goal is to learn about current research projects at our institute, to strengthen our expertise in the field, to provide a platform where research challenges can be discussed, and also to practice scientific presentations.

Content
Current research at the IVC will be presented and discussed.

Prerequisites / notice
This course requires solid knowledge in the area of Computer Graphics and Computer Vision as well as state-of-the-art research.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-5255-10L</td>
<td>Foundations of Reinforcement Learning (Only Assignments)</td>
<td>W  2</td>
<td>4A</td>
<td>N. He</td>
</tr>
</tbody>
</table>

Content
This course focuses on theoretical and algorithmic foundations of reinforcement learning, through the lens of optimization, modern approximation, and learning theory. The course targets students with strong research interests in reinforcement learning, optimization under uncertainty, and data-driven control.

Doctoral Department of Computer Science - Key for Type

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

Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Doctoral Dep. of Information Technology and Electrical Engineering


Doctoral and Post-Doctoral Courses

A minimum of 12 ECTS credit points must be obtained during doctoral studies.

The courses on offer below are only a small selection out of a much larger available number of courses. Please discuss your course selection with your PhD supervisor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0371-00L</td>
<td>Advanced Model Predictive Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>M. Zeilinger, A. Carron, L. Hewing, J. Köhler</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 60.</td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
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<td>Topics include: Review of Bayesian statistics, stochastic systems and Stochastic Optimal Control, Nominal MPC for uncertain systems (nominal robustness), Robust MPC, Stochastic MPC, Set-membership Identification and robust data-driven MPC, Bayesian regression and stochastic data-driven MPC, MPC as safety filter for reinforcement learning.</td>
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<td>Lecture notes</td>
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<td>Lecture notes will be provided.</td>
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<td>Prerequisites / notice</td>
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<td>Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control) strongly recommended. Background in linear algebra and stochastic systems recommended.</td>
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<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<td>Objective</td>
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<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<tr>
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<td>Content</td>
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<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; Gaussian random variables; singular-value decomposition; kernel methods, neural networks, and more</td>
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<td>Lecture notes</td>
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<td>Lecture notes will be handed out as the course progresses.</td>
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<td>Prerequisites / notice</td>
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<td>solid basics in linear algebra and probability theory</td>
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<tr>
<td>227-0146-00L</td>
<td>Analog-to-Digital Converters</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>A. Loeliger</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<td>This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.</td>
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<td>Abstract</td>
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<td>Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. The student will learn to understand the basic principles behind data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained with their principle of operation accompanied with the appropriate mathematical calculations, including the effects of non-idealities in some cases. After successful completion of the course the student should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.</td>
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<tr>
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<td>Objective</td>
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<td></td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<td>Content</td>
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<td>- Introduction: information representation and communication; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy. - Dual-slope &amp; successive approximation register (SAR) converters: dual slope principle &amp; converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array. - Algorithmic &amp; pipelined A/D converters: algorithmic conversion principle; sample &amp; hold stage; pipelined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction. - Performance metrics and non-linearity: ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance. - Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation. - Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter. - Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-oder delta-sigma modulation, circuit level implementation; clock-jitter &amp; SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator. - Digital-to-analog converters: introduction; current scaling D/A converter, current steering DAC, calibration for improved performance.</td>
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<tr>
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<td>Lecture notes</td>
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<td>Slides are available online under <a href="https://lis-students.ee.ethz.ch/lectures/analog-to-digital-converters/">https://lis-students.ee.ethz.ch/lectures/analog-to-digital-converters/</a></td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
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<td>It is highly recommended to attend the course &quot;Analog Integrated Circuits&quot; of Prof. T. Jang as a preparation for this course.</td>
</tr>
<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>A. Iannelli</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.</td>
</tr>
</tbody>
</table>

Objective
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

Content
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes
Available on the course Moodle platform.

Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.
Selected topics of the current research activities at the IEF and closely related institutions are discussed. Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics of randomized methods for problems in different areas. The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.
- Structural characterization and ferroic state investigation by force microscopy and by laser-optical techniques will be addressed.
- Oxide electronics device concepts will be discussed.
- Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal. Particularly interesting phenomena occur in films showing magnetic or electric order or, even better, both of these ("multiferroics").

In this course students will obtain an overarching view on oxide thin epitaxial films and heterostructures design, reaching from their growth by pulsed laser deposition to an understanding of their magnetoelectric functionality from advanced characterization techniques. Students will therefore understand how to fabricate and characterize highly oriented films with magnetic and electric properties not found in nature.

Types of ferroic order, multiferroics, oxide materials, thin-film growth by pulsed laser deposition, molecular beam epitaxy, RF sputtering, structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic proof techniques and to use them autonomously on related problems. Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

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- Structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

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- Structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

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- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.
- Structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.
### Doctoral Studies in Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>364-1013-05L</td>
<td>Organizational Behavior</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>to be announced</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>Organizational behavior concerns the study of individual and group-level processes in organizations like creativity, motivation, and leadership. In this PhD course, an overview of major concepts and research insights in organizational behavior is provided. The participants are encouraged to discuss their own work situation as PhD students in relation to the OB insights covered in the course.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>The objectives of the course are:</td>
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<td>• to provide an overview of OB research</td>
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<td>• to discuss major research streams in OB</td>
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<td>• to enable students to reflect their own work situation based on concepts used in OB.</td>
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<tr>
<td>364-1013-06L</td>
<td>Marketing Theory</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>F. von Wangenheim</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The course is taught Florian Wangenheim (ETHZ)</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td>The purpose of the course is to confront students with current theoretical thinking in marketing, and currently used theories for understanding and explaining buyer and customer behavior in response to marketing action.</td>
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<td><strong>Content</strong></td>
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<td>In the first class, current understanding of the marketing literature and marketing thought is discussed. In the following classes, various theories are discussed, particularly in light of their importance for marketing. Economic, psychological and sociological theory will be related to current marketing thought.</td>
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<tr>
<td>364-1110-00L</td>
<td>Foundations of Innovation Studies</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Brusoni, D. Laureiro Martinez</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>This course will introduce some of the major theoretical threads and controversies in the broad field of innovation. During the first part of the course, the emphasis will be on the evolution of innovation studies. The final part of the course will focus on one of the directions in which those studies have evolved: the field of managerial cognition.</td>
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<td><strong>Objective</strong></td>
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<td>Students will learn about various perspectives, examine different methodologies, explore some original empirical research, make connections between theory and empirical research, and practice reviewing and identifying insight in research.</td>
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<td>1) Be able to display some knowledge on a few major theoretical streams in the area.</td>
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<td>2) Be familiar with the methods, issues and current gaps in the area.</td>
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<td>3) Have practiced skills in finding insight and reviewing the literature.</td>
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<td>4) Have practiced skills in defining research problems and proposing empirical research in this area.</td>
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<tr>
<td>364-0553-00L</td>
<td>Innovation in Digital Space</td>
<td>W</td>
<td>1</td>
<td>1G</td>
<td>G. von Krogh</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>The purpose of this course is to review and discuss issues in current theory and research relevant to innovation in the digital space.</td>
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<td><strong>Objective</strong></td>
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<td>Through in-depth analysis of published work, doctoral candidates will identify and appraise theoretical and empirical studies, formulate research questions, and improve the positioning of their own research within the academic debate.</td>
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<td><strong>Content</strong></td>
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<td>The Internet has a twofold impact on the way individuals and firms innovate. First, firms increasingly draw on digital technology to access and capture innovation-relevant knowledge in their environment. Second, individuals, firms, and other organizations extensively utilize the Internet to create, diffuse, and commercialize new digital products and services. During the past decade, theory and research on innovation in the digital space has flourished and generated extensive insights of relevance to both academia and management practice. This has brought us better understanding of working models, and some fundamental reasons for innovation success or failure. A host of new models and research designs have been created to explore the innovation in the digital space, but these have also brought out many open research questions. We will review some of the existing streams of work, and in the process explore a new research agenda.</td>
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<td><strong>Format</strong></td>
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<td>The course is organized in one block of 2 days. The course is a combination of pre-readings, presentations by faculty and students, and discussions. The students prepare presentations of papers in order to facilitate analysis and discussion.</td>
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</table>
Hacking for Social Sciences is a guide to programming with data. It is tailored to the needs of a field in which scholars' typical curricula do not contain a strong programming component. Yet this course argues that what the open source community calls a 'software carpentry' is no longer just software development. It is also the backbone of collaboration in distributed teams. The third and final block focuses on data themselves from languages such as R and Python to container technology such as docker. The second block focuses on git version control, the de facto industry standard to manage source code. Version control is not only crucial to knowledge management and reproducible research, but it is also the backbone of collaboration in distributed teams. The third and final block focuses on data themselves from languages such as R and Python to container technology such as docker.

The first block demonstrates the components of a modern data science tech stack, classifies technologies and gives a big picture overview: from languages such as R and Python to container technology such as docker. The second block focuses on git version control, the de facto industry standard to manage source code. Version control is not only crucial to knowledge management and reproducible research, but it is also the backbone of collaboration in distributed teams. The third and final block focuses on data themselves from languages such as R and Python to container technology such as docker.

The vast majority of data has been created within the last decade. As a result, more and more fields of research start to consider and embrace programming to process and analyse data. This course teaches applied programming with data and aims to leverage the open source communities, technologies and tools that have emerged particularly within the last decade. Hacking for Social Sciences teaches how to use git version control to collaborate professionally, make your research reproducible and your code base persistent. Non-Goals:

- Understand the role of focal components in a data science tech toolbox.
- Learn how technologies like R, Python, Git Version Control, docker or Cloud Computing could play together in your research project.
- Learn how to manage and version control source code.
- Hacking for Social Sciences teaches how to use git version control to collaborate professionally, make your research reproducible and your code base persistent.
- Applied data sourcing and data transformation
- Learn how to communicate with SQL databases. Learn how to consume data from different sources using machine to machine communication interfaces (APIs) such as the OpenStreetMap geocoding API / Routing Engine or the KOF data API for macroeconomic time series.
- Non-Goals:
- Hacking for Social Sciences is not a Statistics, Econometrics or Machine Learning course. Though experience in these fields will help inasmuch that students will have an easier time to motivate investing in programming and to come up with their own application examples, profound methodological knowledge is not a prerequisite.
- The course contains three blocks that are mostly based on the three learning objectives presented above. Hacking for Social Sciences explicitly plans to spread its three blocks over 1-2 months to give students the ability to work on applied examples in between sessions in order to get most out of the subsequent session. The first block is a basic introduction to data science tools and technologies, and it is designed to give students a solid understanding of these tools and technologies so that they can start using them in their research. The second block focuses on version control, the de facto industry standard to manage source code. Version control is not only crucial to knowledge management and reproducible research, but it is also the backbone of collaboration in distributed teams. The third and final block focuses on data themselves from languages such as R and Python to container technology such as docker.

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The idea behind Hacking for Social Sciences is to build a solid understanding of core technologies and concepts to help researchers develop their own custom software solutions. The book/script will be available from https://h4sci.github.io/h4sci-book/. The book/script is a free and open online book (made with bookdown) is available from https://h4sci.github.io/h4sci-book/. The book/script is a free and open online book (made with bookdown) is available from https://h4sci.github.io/h4sci-book/.

Lecture notes A free and open online book (made with bookdown) is available from https://h4sci.github.io/h4sci-book/. The book/script will be continuously updated during the course to account for questions and participants' questions.

All course materials including, slides, resources and source code will be made available through: https://h4sci.github.io/
Remark: The list might change. Students will be informed about the changes before the first session.

The course focuses on important factors that drive the innovation performance of firms, like innovation capabilities, the use of digital technologies, environmental and innovation policy and it shows how innovation activities relate to firm performance and to the technological dynamics of industries. We also discuss the implications of the findings for effective economic policy-making.

The course provides students with the basic skills to understand and assess empirically the technological activities of firms and the technological dynamics of industries. In addition, the aim is to promote the understanding of the essential criteria for innovation policy-making.

Personal and social skills are also addressed during the course. In particular, there is the possibility to improve communication and presentation skills, the ability to develop arguments for the positions of political representatives, policy-makers, pressure groups, or NGOs in connection with innovation policy-making.

Abstract
Recent developments in the fields of contract theory, finance, banking, money and macroeconomics.

Objective
Understanding recent developments in the fields of contract theory, finance, banking and macroeconomics.

Prerequisites / notice
In each session, students will have three assignments:

1) prepare for in-depth discussion of all papers. The students are supposed to read in advance all the papers that will be presented in the sessions.
2) critically review and discuss the assigned papers. Assignments will be done after participants confirm their presence.
3) submit in advance a short critique of the assigned papers - max 2 pages.

Doctoral Studies in Economics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>364-1090-00L</td>
<td>Research Seminar in Contract Theory, Banking and Money (University of Zurich)</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>H. Gersbach, University lecturers</td>
</tr>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td>UZH Module Code: DOE0988</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<tr>
<td>363-1036-00L</td>
<td>Empirical Innovation Economics</td>
<td>W</td>
<td>3 credits</td>
<td>1G</td>
<td>M. Wörter</td>
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<td>The course focuses on important factors that drive the innovation performance of firms, like innovation capabilities, the use of digital technologies, environmental and innovation policy and it shows how innovation activities relate to firm performance and to the technological dynamics of industries. We also discuss the implications of the findings for effective economic policy-making.</td>
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<td>The course provides students with the basic skills to understand and assess empirically the technological activities of firms and the technological dynamics of industries. In addition, the aim is to promote the understanding of the essential criteria for innovation policy-making.</td>
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<td>Personal and social skills are also addressed during the course. In particular, there is the possibility to improve communication and presentation skills, the ability to develop arguments for the positions of political representatives, policy-makers, pressure groups, or NGOs in connection with innovation policy-making.</td>
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The course consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about digitization of firms, data about environmentally friendly innovations, or patent data. In part I we will learn about: (a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. (b) the role of competition and market structure for the R&D activities of companies. (c) how digital and environmentally friendly technologies diffuse among firms. (d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. (e) how we can measure the returns to R&D activities. (f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.


The course is directed to advanced Master-Students and PhD Students with an interest in empirical work.

**Content**

The course consists of two parts. Part I provides an introduction into important topics in the field of the economics of innovation. Part II consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about digitization of firms, data about environmentally friendly innovations, or patent data. In part I we will learn about: (a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. (b) the role of competition and market structure for the R&D activities of companies. (c) how digital and environmentally friendly technologies diffuse among firms. (d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. (e) how we can measure the returns to R&D activities. (f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.

**Lecture notes**

Will be provided in the course and in the e-learning environment: https://moodle-app2.let.ethz.ch/course/view.php?id=15120

**Literature**

Literature will be presented in the course. For an introduction into the economics of innovation see G.M. Peter Swann, The Economics of Innovation - An Introduction. Edward Elgar, 2009.


**Prerequisites / notice**


Bitte spezielle Ankündigungen beachten.

Studierende des GESS-Pflichtwahlfachs sollten sich vor Beginn mit der Seminarleitung in Verbindung setzen.

**Taught competencies**

- Domain A - Subject-specific Competencies: Concepts and Theories, assessed; Techniques and Technologies, assessed.
- Domain B - Method-specific Competencies: Analytical Competencies, assessed; Decision-making, assessed; Media and Digital Technologies, assessed; Problem-solving, assessed; Project Management, not assessed.
- Domain C - Social Competencies: Communication, assessed; Cooperation and Teamwork, not assessed; Customer Orientation, not assessed; Leadership and Responsibility, not assessed; Self-presentation and Social Influence, not assessed; Sensitivity to Diversity, not assessed; Negotiation, not assessed.
- Domain D - Personal Competencies: Adaptability and Flexibility, not assessed; Creative Thinking, not assessed; Critical Thinking, assessed; Integrity and Work Ethics, not assessed; Self-awareness and Self-reflection, not assessed; Self-direction and Self-management, assessed.

**364-0531-00L CER-ETH Research Seminar**

- **Objective**: Understanding cutting-edge results of current research in the fields of the CER-ETH Professors.
- **Content**: Referate zu aktuellen Forschungsergebnissen aus den Bereichen Ressourcen- und Umweltökonomie, theoretische und angewandte Wachstums- und Aussenwirtschaftstheorie sowie Energie- und Innovationsökonomie von in- und ausländischen Gastreferierenden sowie von ETH-internen Referierenden.
- **Prerequisites / notice**: Bitte spezielle Ankündigungen beachten.

**364-0556-00L Doctoral Workshop: Astute Modelling**

- **Prerequisites**: Students are expected to attend the course 364-0559-00L "Dynamic Macroeconomics (Doctoral Course)", before registering for this workshop.
- **Objective**: We will learn how to craft models, how to present our own research and improve our analytical skills.
- **Prerequisites / notice**: Students are expected to attend the doctoral course "Macroeconomic Dynamics" before registering for this workshop.

**364-0585-01L PhD Course: Applied Econometrics**

- **Abstract**: In this course, we will address three blocks of selected problems: (i) estimation of fixed and random effects panel data models for single equations and systems of equations; (ii) estimation of models with endogenous treatment effects or sample selection; (iii) estimation of models with interdependent data (so-called spatial models). Students are expected to attend the doctoral course "Macroeconomic Dynamics" before registering for this workshop.
- **Objective**: The main agenda of this course is to familiarize students with the estimation of econometric problems with three alternative types of problems: (i) estimation of fixed and random effects panel data models for single equations and systems of equations; (ii) estimation of models with endogenous treatment effects or sample selection; (iii) estimation of models with interdependent data (so-called spatial models). Students will be able to program estimation routines for such problems in STATA and apply them to data-sets. They will be given a data-set and will have to work out empirical problems in the context of a term paper.
- **Lecture notes**: For panel data analysis, I will rely on the book: Baltagi, Badi H. (2005), Econometric Analysis of Panel Data, Wiley: Chichester.
- **For sample selection and endogenous treatment effect analysis, I will rely on the book**: Wooldridge, Jeffrey M. (2002), Econometric Analysis of Cross Section and Panel Data, MIT Press: Cambridge, MA.
- **For spatial econometrics**: I will mostly use papers.
- **I will prepare a script (based on slides), covering all topics.**
This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists

364-1025-00L  Advanced Microeconomics  E-  3 credits  2G  A. Bommier

Abstract  The objective of the course is to provide students with advanced knowledge in some areas of micro economic theory. The course will focus on 1) Individual behavior 2) Collective behavior 3) Choice under uncertainty 4) Intertemporal choice.

Objective  The aim is to give to the students the opportunity to review the key results in rational individual behavior, collective models, choice under uncertainty, and intertemporal choice, as well as to get some insights on more recent advances in those areas.

Content  The course is therefore designed for students who have some interest for research in economics.

Literature  The course will be based on some chapters of the books "Advanced Microeconomic Theory" by Jehle and Reny (2011) and "Microeconomic Theory", by Mas-Colell, Whinston and Green (1995), as well as research articles for the most advanced parts.

364-1058-00L  Risk Center Seminar Series  Z  0 credits  2S  B. J. Bergmann

Abstract  This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists of presentations and subsequent discussions in the area of modeling complex socio-economic systems and crises. Students and other guests are welcome.

Objective  Participants should learn to get an overview of the state of the art in the field, to present it in a well understandable way to an interdisciplinary scientific audience, to develop novel mathematical models for open problems, to analyze them with computers, and to defend their results in response to critical questions. In essence, participants should improve their scientific skills and learn to work scientifically on an internationally competitive level.

Content  This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists of presentations and subsequent discussions in the area of modeling complex socio-economic systems and crises. For details of the program see the webpage of the colloquium. Students and other guests are welcome.

Literature  Literature will be provided by the speakers in their respective presentations.

Prerequisites / notice  Participants should have relatively good mathematical skills and some experience of how scientific work is performed.

364-1015-00L  KOF-ETH-UZH International Economic Policy Seminar  W  2 credits  2S  P. Egger, J.-E. Sturm, University lecturers (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: DOE0584

Abstract  In this seminar series, which is held jointly with Prof. Dr. Wolte and Prof. Dr. Hoffman from the University of Zurich, distinguished international researchers present their current research related to international economic policy. The participating doctoral students are expected to attend the presentations (bi-weekly). Moreover, a critical review has to be prepared for 1 of the papers presented.

Objective  On the one hand, participating students are exposed to research at the frontier of international economic policy research. On the other hand, skills such as critical thinking and preparing reviews are learned.

364-0513-00L  Empirical Methods in Energy and Environmental Economics  W  3 credits  2V  M. Filippini

Abstract  This course is designed for PhD & advanced Masters students who are interested in energy and environmental economics. The focus of the lectures/seminars is on methods of applied econometrics in these fields. The course is composed of lectures on specific topics and a seminar. In the seminar, students will have an opportunity to present own papers or to present and discuss empirical studies.

Objective  The objectives of this course are twofold: first, students will learn about the application of econometric techniques in the fields of energy and environmental economics. Second, through the presentation of their papers or the presentation and discussion of the existing literature, students will also get a sense of how critical thinking can be used to assess empirical research in energy and environmental economics.
Day 1: Thursday, January 9
09:00 – 10:30 Session 1: Multinomial choice, heterogeneity (instructor: Greene)
11:00 – 12:30 Session 2: Multinomial choice, heterogeneity (instructor: Greene)
13:30 – 15:00 Session 3: Latent class and Mixed logit (instructor: Greene)
15:30 – 16:30 Session 3: Latent class and Mixed logit (instructor: Greene)
Day 2: Friday, January 10
08:30 – 10:00 Session 1: Measurement of the energy efficiency (instructor: Filippini)
10:30 – 12:00 Session 2: Structural models (instructor: Houde)
13:00 – 14:30 Session 3: Student Presentations
15:00 – 16:30 Session 3: Student Presentations
Day 3: Saturday, January 11
08:30 – 09:30 Session 1: Seminar by Prof. Kenneth Gillingham (Yale University)
09:30 – 10:30 Session 1: Seminar by Prof. Beat Hintermann (Basel University)
10:30 – 11:30 Session 1: Seminar by Prof. Matt Kotchen (Yale University)
10:30 – 12:30 Session 2: Student Presentations
13:30 – 15:30 Session 3: Student Presentations

Lecture notes
Lecture notes will be made available to the students.

Prerequisites / notice
Students are expected to have attended courses in advanced microeconomics and in econometrics.

364-1062-00L Experimental Methods W 1 credit 1V C. Waibel

Abstract
This course introduces PhD students into the principles of experimental methods in economics and outlines how to prepare, conduct and evaluate an experiment.

Objective
This course aims to prepare PhD students for conducting their own experiment.

Content
1. Introduction: What are economic experiments and why to use them?
4. Conducting experiments: Instructions, testing, recruiting, sessions.
5. Measuring techniques: Eliciting beliefs, risk attitudes, social preferences.
7. Participants' presentations & discussion of their experimental design

Literature
Books:

Basic Articles:

A reading list with articles for each lecture will be published in Moodle.

Prerequisites / notice
Students who have successfully completed the course "Dynamic Macroeconomics" (364-0559-00L) or "Economics of Innovation and Growth" (363-0562-01L) can not register for this course.

363-1136-00L Dynamic Macroeconomics, Innovation and Growth W 3 credits 2V H. Gersbach

Abstract
Introducing dynamic models and workhorses in macroeconomics, understanding the role of innovation and institutions for economic development and discussing policies to foster innovation and economic growth, with a perspective on how digitization and artificial intelligence will affect our economies.

Objective
After the course, students will be familiar with dynamic general equilibrium theory and the basic workhorses in macroeconomics. Students will understand how the world has developed over the last centuries and the proximate and fundamental causes of innovation and economic growth. Students will understand and apply the basic models of economic growth and will be able to identify policies to foster innovation and growth and to reduce the large wealth differences in the world. Finally, they understand how digitization and artificial intelligence will drive the economies.

Content
1. Introduction
2. The Arrow-Debreu Approach and Sequential Markets
3. The Neoclassical Growth Model and the Representative Agent Model (with Mathematical Background)
4. Technological Progress and how the World has developed
5. Innovations and Growth (New Growth Theory)
6. Growth Policies and Fundamental Causes for Growth
7. Digitization and Artificial Intelligence


14. Current Literature on Digitization and Artificial Intelligence

Prerequisites / notice Students who have successfully completed the course "Dynamic Macroeconomics" (364-0559-00L) or "Economics of Innovation and Growth" (363-0562-01L) can not register for this course.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>364-1064-00L</td>
<td>Inaugural Seminar - Doctoral Retreat</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>P. Schmid, S. Brusoni, R. Finger, G. Grote, T. Netland, F. von Wangenheim, to be announced</td>
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</table>

Abstract

This course is geared towards first and second-year doctoral candidates of MTEC. It is held as a workshop style. Students attending this seminar will benefit from interdisciplinary discussions and insights into current and future work in business and economics research.

Objective

The purpose of this course is to
- introduce doctoral candidates to the world of economics, management and systems research at MTEC
- make doctoral candidates aware of silo-thinking in the specific sub-disciplines and encourage them to go beyond those silos
- discuss current issues with regard to substantive, methodological and theoretical domains of research in the respective fields

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**Doctoral Department of Management, Technology, and Economics - Key for Type**

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

**Key for Hours**

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

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

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Special students and auditors need special permission from the lecturers.
With manufacturing processes reaching its limits in terms of transistor density on today's computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the "think parallel" mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

Content
1. Hardware and Architecture: Moore's Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn's taxonomy, Vector instructions (for Intel x86)

2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)

3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models

4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl's Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

Lecture notes
https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/
Class notes, handouts

Literature
- An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann
- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann
- Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press
- Lecture notes

Prerequisites / notice
Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

Doctoral Department of Mechanical and Process Engineering

Doctoral and Post-Doctoral Courses

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<tr>
<th>Number</th>
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<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCE) I</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.</td>
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<td>With manufacturing processes reaching its limits in terms of transistor density on today's computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the &quot;think parallel&quot; mind-set of developers is still lagging behind.</td>
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<td>Content</td>
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<tr>
<td></td>
<td>1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)</td>
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151-0111-00L Research Seminar in Fluid Dynamics Internal research seminar for graduate students and scientific staffs of the IFD  E- 0 credits 2S  F. Coletti, P. Jenny, T. Rösgen, O. Supponen

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<th>Number</th>
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<tr>
<td>151-0123-00L</td>
<td>Experimental Methods for Engineers</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>T. Rösgen, B. Schuermans, M. Tibbitt</td>
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<tr>
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<td>Abstract</td>
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<td>The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial in-class introduction, laboratory exercises from different application areas (especially in thermofluidics and process engineering) are attended by students in small groups.</td>
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<td>Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic applications. Understanding of various sensing technologies and analysis procedures. Exposure to typical experiments, diagnostics hardware, data acquisition and processing. Study of applications in the laboratory.</td>
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<td>Fundamentals of scientific documentation &amp; reporting. In-class introduction to representative measurement techniques in the research areas of the participating institutes (fluid dynamics, energy technology, process engineering) Student participation in 8-10 laboratory exercises (study groups of 3-5 students, dependent on the number of course participants and available experiments) Lab reports for all attended experiments have to be submitted by the study groups. A final exam evaluates the acquired knowledge individually.</td>
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<td>Lecture notes</td>
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<td>Presentations, handouts and instructions are provided for each experiment.</td>
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<td>Literature</td>
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<td>Prerequisites / notice</td>
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<td>Basic understanding in the following areas:</td>
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<td>- fluid mechanics, thermodynamics, heat and mass transfer</td>
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<td>- electrical engineering / electronics</td>
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<td>- numerical data analysis and processing (e.g. using MATLAB)</td>
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151-0529-00L Computational Mechanics II: Nonlinear FEA W 4 credits 2V+2U L. De Lorenzis

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<tr>
<th>Number</th>
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<tr>
<td>151-0529-00L</td>
<td>Computational Mechanics II: Nonlinear FEA</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>L. De Lorenzis</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).</td>
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<td>To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.</td>
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<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>1. Introduction: various sources of nonlinearities and implications for FEA.</td>
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<td>Lecture notes</td>
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<td>Lecture notes will be provided. However, students are encouraged to take their own notes.</td>
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</table>
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

Familiarize students with main architectural principles and concepts of embedded control systems. An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

Prerequisite courses are Control Systems I and Informatics I.

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch)

After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls.

Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems---controls--151-0623-0.html for a list of upcoming lectures.

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls. MSc students in Robotics, Systems, and Controls are required to attend every lecture. Attendance will be monitored. If for some reason a student cannot attend one of the lectures, the student must select another ETH or University of Zurich seminar related to the field and submit a one page description of the seminar topic. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems---controls--151-0623-0.html for a suggestion of other lectures.

Students are required to attend all seven lectures to obtain credit. If a student must miss a lecture then attendance at a related special lecture will be accepted that is reported in a one page summary of the attended lecture. No exceptions to this rule are allowed.

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Current advanced research activities in the areas of thermo- and fluid dynamics are presented and discussed, mostly by external speakers.

This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to:
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world”
- “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- debate the merits of international engineering in popular culture and media
- propose improved SDG indicators that address current shortcomings
- compare the engineering curricula of different countries to identify relative strengths and shortcomings
- explain the inherent biases of academic publishing and its impact on engineering failure
- analyze linkages between the rise of philanthropy and strategic priority areas
- recommend equitable, just funding models to achieve more sustainable outcomes
- formulate a vision for the international engineer of the future
Content
Role of international engineering during colonialism
Transition of international engineering following colonialism
White saviourism and racism in international engineering
International engineering in popular culture
The missing role of Engineering Education
Biases academic publishing
The emerging role in Global Philanthropy
The paradox of international funding

Literature

151-9901-00L Scientific Writing for Publication in Engineering ■ W 2 credits 1G S. Milligan
Only for D-MAVT doctoral students.

Abstract
Scientific Writing for Publication in Engineering is a short course (5 half-day workshops) designed to help junior researchers develop the skills needed to write their first research articles in English.

Objective
The course deals with topics such as:
- Fitting texts to target readerships and journals
- Managing the writing process efficiently
- Structuring each section of the text effectively
- Producing fluent and reader-focused sentences and paragraphs
- Editing the text before submission
- Revising in response to reviewers’ comments.

Content
Participants produce a number of short texts as homework assignments and receive detailed individual feedback on these during the course.
The course takes place at times and locations chosen to suit MAVT doctoral researchers. Content and materials deal specifically with the demands of writing in engineering research fields. Wherever feasible, elements of participants’ future research articles are developed as assignments within the course, so it is particularly useful for those who have their data and are about to begin the writing process.

151-9902-00L Workshop on Intellectual Property Rights ■ W 1 credit 2S
Does not take place this semester.

Abstract
The workshop is an introduction to intellectual property rights. It informs participants about the different methods of protecting technical know-how and puts them in a position to use this knowledge for their own research. The workshop includes exercises and use cases tailored to mechanical engineers. A section on IP strategy and commercialization rounds up the program.

Objective
Knowledge about patents and other intellectual property (IP) rights has become increasingly important for scientists in the field of mechanical engineering. In fact, many PhD students disclose their first inventions here at ETH Zurich. The workshop is an excellent introduction to the fundamental aspects of intellectual property (IP) rights and prepares you well for your first patent application.

Content
Presentations and exercises on intellectual property rights (what is new? what is inventive? what is the role of a patent claim?), patent search, invention disclosures at ETH Zurich, commercialization of an invention by an ETH spin-off.

Lecture notes
Presentation slides.

Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercisecs) 351-0778-01.

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a “lecture-style” approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a “pitch” with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

This course is an introduction to the critical management skills involved in planning, organizing, leading and controlling an organization. All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

Creative Thinking

Students who take this course will increase their knowledge of marketing, its effect on consumer behavior and its role in creating long-term value. The course will introduce important concepts, frameworks and methods for marketing decision-making. A focus will be on managing complexity and uncertainty, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will further discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between these elements and on the application of a selection of tools and methods.

Concepts and Theories

This course follows a 'systemic' view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will further discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between these elements and on the application of a selection of tools and methods.

Adaptability and Flexibility

This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change.

Decision-making

Students who take this course will increase their knowledge of marketing, its effect on consumer behavior and its role in creating long-term value. The course will introduce important concepts, frameworks and methods for marketing decision-making. A focus will be on managing customer relationships with the help of targeted promotions and data collected through digital technologies.
The learning objectives of the course are:

1) Define what marketing is and describe its role at different stages of the value chain
2) Apply psychological theories to analyze behavior (e.g., purchase behavior) and identify the needs of (prospective) customers in consumer and business markets
3) Design elements of the marketing mix—e.g., develop new products and set prices—in a way that creates long-term value
4) Create an effective and efficient marketing mix that attracts and engages customers, e.g., by running targeted promotions
5) Use quantitative methods and customer data to manage relationships with customers

The course will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science studies. The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking not assessed</td>
</tr>
</tbody>
</table>

The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

The learning objectives of the course are:

(1) Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and describe firm and consumer behaviour. (4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.

The structure of the course will roughly follow the different steps of the value chain, i.e., the set of activities necessary for offering valuable products to customers. First, it will introduce students to psychological theories that help explain behavior, e.g., purchase behavior. It will also familiarize students with different methods from marketing research, which can be used to identify the needs of customers. Next, the course will look at the role of the marketing mix in satisfying customer needs. For example, the class will cover new product development and pricing. A focus will be on managing profitable, long-term relationships with customers. To this end, students will gain in-depth knowledge on the use of targeted promotions and marketing data to (1) attract, (2) convert and engage and (3) retain customers.

The course is designed to be “hands-on”, with opportunities to apply skills on business cases involving real-world marketing data. It will feature guest lectures from industry experts.

The class might be taught in an in-person, remote or in a hybrid format.

The course will look at the role of the marketing mix in satisfying customer needs. For example, the class will cover new product development and pricing. A focus will be on managing profitable, long-term relationships with customers. To this end, students will gain in-depth knowledge on the use of targeted promotions and marketing data to (1) attract, (2) convert and engage and (3) retain customers.

The course will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science studies. Thus, the goal of the lecture “Principles of Microeconomics” is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

Lecture notes
Lecture notes, exercises and reference material can be downloaded from Moodle.

Literature

The book can also be used for the course ‘Principles of Macroeconomics’ (Sturm)

For students taking only the course ‘Principles of Microeconomics’ there is a shorter version of the same book:

Complementary:

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tbody>
</table>

### 363-0511-00L Managerial Economics

**Not for MSc students belonging to D-MTEC!**

<table>
<thead>
<tr>
<th>Domain</th>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>363-0511-00L</td>
<td>Managerial Economics</td>
<td>W</td>
<td>4 credits</td>
</tr>
<tr>
<td></td>
<td>363-0565-00L</td>
<td>Principles of Macroeconomics</td>
<td>W</td>
<td>3 credits</td>
</tr>
<tr>
<td></td>
<td>363-0711-00L</td>
<td>Accounting for Managers</td>
<td>W</td>
<td>3 credits</td>
</tr>
</tbody>
</table>

#### Abstract

"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management. The set-up of the course will closely follow the book of Microeconomics by Robert Pindyck & Daniel Rubinfeld, 9th edition 2018. The Pearson series in economics.

#### Objective

The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

#### Literature

- Microeconomics by Filippini.
- Economics, Filippini.
- Economics, Filippini.

#### Prerequisites / notice

The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

#### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Critical Thinking</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>
The course Accounting for Managers offers an introduction to financial accounting and management accounting. It provides managers with the necessary knowledge for decision making using accounting information. By attending this course, students will be able to:
- record business transactions on the different types of accounts.
- establish a balance sheet and an income statement.
- prepare the different financial reports.
- understand the principles of cost accounting.
- determine the cost of production.
- make decisions based on cost information.

The first part of the course is devoted to financial accounting. It teaches the principles of double-entre accounting and deals with the recording of commercial transactions on accounts. It describes the work to be carried out at the closing in order to prepare the financial reports according to the generally accepted accounting principles. This type of accounting information is primarily intended for investors and shareholders.

The second part of the course describes the principles of management accounting and explains the different costing methods. It aims to determine the manufacturing cost of production of the different products and services using full and variable costing methods. The accounting information focuses on the internal needs of managers for the purpose of budget preparation and profitability analysis.

363-0790-00L Technology Entrepreneurship W 2 credits 2V F. Hacklin

Objective
This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Content
See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

363-1020-00L Monetary Policy W 3 credits 2V J.-E. Sturm, A. Rathke

Objective
This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

Content
A critical understanding of dos and don'ts is provided through highlighting and discussing real-life examples and cases.

401-0625-01L Applied Analysis of Variance and Experimental Design W 5 credits 2V+1U L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial designs, and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.
Content Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.


Prerequisites / notice The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

<table>
<thead>
<tr>
<th>Course</th>
<th>Lecturers</th>
<th>Credits</th>
<th>Type</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0546-00L</td>
<td>A. Koepf, P. Pliska</td>
<td>W 1</td>
<td>V</td>
<td>Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics. Introduction into intellectual property; prosecution of patent applications; patent information; exploitation and enforcement of patents; peculiarities in pharmaceutics and medicine; social, political and ethical aspects; Trademarks.</td>
</tr>
<tr>
<td>535-0546-00L</td>
<td>S. Panke</td>
<td></td>
<td></td>
<td>Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.</td>
</tr>
<tr>
<td>636-0507-00L</td>
<td>S. Panke, Y. Benenson, J. Stelling</td>
<td>W 8</td>
<td>A</td>
<td>Students in the MSc Biotechnology (Programme Regulations 2017) may select Synthetic Biology II instead of the Research Project I.</td>
</tr>
<tr>
<td>851-0180-00L</td>
<td>G. Achermann, P. Emch</td>
<td>W 2</td>
<td>G</td>
<td>Particularly suitable for students of D-BIOL, D-CHAB, D-HEST.</td>
</tr>
</tbody>
</table>

Prerequisites / notice None

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Prerequisites / notice
- Handouts during course
- The final presentation of the project is typically at the MIT (Cambridge, US). Other competing schools include regularly Imperial College, Cambridge University, Harvard University, UC Berkeley, Princeton University, CalTech, etc.

6 months biological design project, during which the students are required to give presentations on advanced topics in synthetic biology (specifically genetic circuit design) and then select their own biological system to design. The system is subsequently modeled, analyzed, and experimentally implemented. Results are presented at a national student competition at the MIT (Cambridge).

Objective The students are supposed to acquire a deep understanding of the process of biological design including model representation of a biological system, its thorough analysis, and the subsequent experimental implementation of the system and the related problems.

Content Presentations on advanced synthetic biology topics (eg genetic circuit design, adaptation of systems dynamics, analytical concepts, large scale de novo DNA synthesis), project selection, modeling of selected biological system, design space exploration, sensitivity analysis, conversion into DNA sequence, (DNA synthesis external,) implementation and analysis of design, summary of results in form of scientific presentation and poster, presentation of results at the iGEM international student competition (www.igem.org).

Lecture notes A script is provided in electronic form during the lecture.

Prerequisites / notice

Number of participants limited to 40

2G

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

**Objective**

Participants of the course Research Ethics will

- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;

**Content**

I. Introduction to Moral Reasoning

1. Ethics - the basics
   1.1 What ethics is not... 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
   2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
   3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities

1. Integrity in research and research misconduct
   1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
   2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
   3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities

1. Research involving human subjects
   1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
   2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
   3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes

Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice

What are the requirements?

First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):

1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Decision-making | assessed |
| Problem-solving | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Cooperation and Teamwork | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| Critical Thinking | assessed |
| Integrity and Work Ethics | assessed |
| Self-awareness and Self-reflection | assessed |

**Doctoral Department of Mechanical and Process Engineering - Key for Type**

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

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

### ECTS

European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Doctoral and Post-Doctoral Courses

**Course Catalogue of ETH Zurich**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-0710-00L</td>
<td>Polymer Physics</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>H. C. Öttinger, M. Kröger</td>
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<tr>
<td></td>
<td>Abstract: Group seminar in polymer physics</td>
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<tr>
<td></td>
<td>Objective: Continued and deeper education</td>
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<td>Content: Presentation and discussion of</td>
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<td>Metal Physics and Technology Seminar</td>
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<td>J. F. Löfler</td>
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<td>Objective: Detailed education of researchers in the area of metallic materials.</td>
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<td>R. Spolenak</td>
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<td>Objective: Detailed education of researchers in the area of nanometallurgy.</td>
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<td>327-1300-00L</td>
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<td>1S</td>
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<tr>
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<td>Objective: Improving the interaction of</td>
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<td>Content: Presentation and discussion of</td>
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<tr>
<td>327-6100-00L</td>
<td>Materials Colloquium</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>M. Fiebig, I. Herrmann, M. Luisier,</td>
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<tr>
<td></td>
<td>Abstract: The Materials Colloquium is a</td>
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<td>Objective: Learn about recent research in</td>
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<td>Content: <a href="https://sam.mat.ethz.ch/nc2021/">https://sam.mat.ethz.ch/nc2021/</a></td>
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<td>327-0721-00L</td>
<td>Writing for Publication in Materials Science</td>
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<td>2</td>
<td>1G</td>
<td>R. Mihalka</td>
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<tr>
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<td>Objective: Writing for Publication in</td>
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<td>Content: Participants will be expected to</td>
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<tr>
<td>327-2125-00L</td>
<td>Microscopy Training SEM I - Introduction</td>
<td>W</td>
<td>2</td>
<td>3P</td>
<td>P. Zeng, A. G. Bittermann, S. Gerstl,</td>
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<tr>
<td></td>
<td>to SEM</td>
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<tr>
<td></td>
<td>The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.</td>
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<td></td>
<td>For PhD students, postdocs and others, a fee will be charged</td>
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</table>
This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopEMSEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

- **Objective**
  - Set-up, align and operate a SEM successfully and safely.
  - Understand important operational parameters of SEM and optimize microscope performance.
  - Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
  - Operate the SEM in low-vacuum mode.
  - Make use of EDX for semi-quantitative elemental analysis.
  - Prepare samples with different techniques and equipment for imaging and analysis by SEM.

- **Content**
  During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

  This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

  **Lectures:**
  - Introduction on Electron Microscopy and instrumentation
  - electron sources, electron lenses and probe formation
  - beam/specimen interaction, image formation, image contrast and imaging modes.
  - sample preparation techniques for EM
  - X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

  **Practicals:**
  - Brief description and demonstration of the SEM microscope
  - Practice on image formation, image contrast (and image processing)
  - Student participation on sample preparation techniques
  - Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
  - Practice on real-world samples and report results

- **Lecture notes**
  Lecture notes will be distributed.

- **Literature**

- **Prerequisites / notice**
  No mandatory prerequisites.
**Prerequisites / notice**

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

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### Doctoral Department of Materials Science - Key for Type

<table>
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<th>Key</th>
<th>Description</th>
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</tbody>
</table>

### ECTS

- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
Over the years, randomization has proven to be a powerful tool in the modeling of risks on several levels: for computational purposes, in the context of high-frequency wave scattering, both SCA and NA share the same goal — that of understanding the behaviour of the scattered wave — but these two fields have operated largely in isolation, mainly because the tools and techniques of the two fields are somewhat disjoint. This by-and-large self-contained course focuses on the Helmholtz equation, which is arguably the simplest possible model of wave propagation. Our first goal will be to show how even relatively-simple tools from semiclassical analysis can be used to prove fundamental results about the numerical analysis of finite-element method applied to the high-frequency Helmholtz equation.

### Number 401-5005-71L Randomization and Dimensionality in Risk Modeling

**Abstract**

Nachdiplom lecture

**Content**

Over the years, randomization has proven to be a powerful tool in the modeling of risks on several levels: for computational purposes, in uncovering connections between different models, but also in the consideration and generation of physical and/or synthetic scenarios in risk management. A second, and in part connected, theme is the parsimonious and structure-preserving refinement of stochastic models via matrix-valued parameters, and related questions concerning the appropriate and effective dimension of models for a given purpose. This lecture will deal with various recent advances in these fields, and also illustrate concrete applications in insurance and finance, including the optimal design of reinsurance treaties and the probabilistic analysis of the profitability of blockchain mining.

**Prerequisites / notice**

The course will aim at being accessible both to students coming from a numerical-analysis/applied-maths background and to students coming from an analysis background.

### Number 401-3225-00L Introduction to Lie Groups

**Abstract**

Topological groups and Haar measure. Definition of Lie groups, examples of local fields and examples of discrete subgroups; basic properties; Lie subgroups. Lie algebras and relation with Lie groups: exponential map, adjoint representation. Semisimplicity, nilpotency, solvability, compactness: Killing form, Lie's and Engel's theorems. Definition of algebraic groups and relation with Lie groups.

**Objective**

The goal is to have a broad though foundational knowledge of the theory of Lie groups and their associated Lie algebras with an emphasis on the algebraic and topological aspects of it.

**Literature**


**Prerequisites / notice**

Topology and basic notions of measure theory. A basic understanding of the concepts of manifold, tangent space and vector field is useful, but could also be achieved throughout the semester.

**Course webpage:** https://metaphor.ethz.ch/x/2018/hs/401-3225-00L/

### Number 401-3533-70L Topics in Riemannian Geometry

**Abstract**

Selected topics from Riemannian geometry in the large: triangle and volume comparison theorems, Milnor’s results on growth of the fundamental group, Gromov-Hausdorff convergence, Cheeger’s diffeomorphism finiteness theorem, the Besson-Courtois-Gallot barycenter method and the proofs of the minimal entropy theorem and the Mostow rigidity theorem for rank one locally symmetric spaces.

**Lecture notes**

Lecture notes will be provided.

### Number 401-3001-61L Algebraic Topology I

**Abstract**

This is an introductory course in algebraic topology, which is the study of algebraic invariants of topological spaces. Topics covered include: singular homology, cell complexes and cellular homology, the Eilenberg-Steenrod axioms.


Book can be downloaded for free at: http://www.math.cornell.edu/~hatcher/AT/ATpage.html

See also: http://www.math.cornell.edu/~hatcher/#anchor1772800

3) E. Spanier, *Algebraic topology*, Springer-Verlag

You should know the basics of point-set topology.

Useful to have (though not absolutely necessary) basic knowledge of the fundamental group and covering spaces (at the level covered in the course "topology").

Some knowledge of differential geometry and differential topology is useful but not strictly necessary.

Some (elementary) group theory and algebra will also be needed.

### Combinatorics II

**W 4 credits**

**2G**

N. Hungerbühler

**Abstract**

The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.

**Objective**

Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

**Content**

Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler's function, Cayley graphs, formal power series, permutation groups, cycles, Bunsdie's lemma, cycle index, Polya's theorems, applications to graph theory and isomers.

### Algebraic Methods in Combinatorics

**W 6 credits**

**2V+1U**

B. Sudakov

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools. One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments
- Spaces of polynomials and tensor product methods
- Eigenvalues of graphs and their application
- The Combinatorial Nullstellensatz and the Chevalley-Warning theorem

Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Lecture notes**

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

**Prerequisites / notice**

Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Harmonic Analysis

**W 4 credits**

**2V**

A. Figalli

**Abstract**

The goal of this class is to give an introduction to harmonic analysis, covering a series of classical important results such as:

1) interpolation theorems
2) convergence properties of Fourier series
3) Calderón-Zygmund operators
4) Littlewood-Paley decomposition
5) Hardy and BMO spaces

**Lecture notes**

I plan to write some notes of the class.

**Literature**

There is no official textbook.

### Microlocal Analysis

**W 6 credits**

**3G**

P. Hintz

**Abstract**

Microlocal analysis is the analysis of partial differential equations in phase space. The first half of the course introduces basic notions such as pseudodifferential operators, wave front sets of distributions, and elliptic parametrices. The second half develops modern tools for the study of nonelliptic equations, with applications to wave equations arising in general relativity.
Objective

Students will be able to analyze linear partial differential operators (with smooth coefficients) and their solutions in phase space, i.e. in the cotangent bundle. For various classes of operators including, but not limited to, elliptic and hyperbolic operators, they will be able to prove existence and uniqueness (possibly up to finite-dimensional obstructions) of solutions, and study the precise regularity properties of solutions.

The first goal is to construct and apply parametrices (approximate inverses) or approximate solutions of PDEs using suitable calculi of pseudodifferential operators (ps.d.o.s). This requires defining ps.d.o.s and the associated symbol calculus on Euclidean space, proving the coordinate invariance of ps.d.o.s, and defining a ps.d.o. calculus on manifolds (including mapping properties on Sobolev spaces).

The second goal is to analyze distributions and operations on them (such as: products, restrictions to submanifolds) using information about their wave front sets or other microlocal regularity information. Students will in particular be able to compute the wave front set of distributions.

The third goal is to infer microlocal properties (in the sense of wave front sets) of solutions of general linear PDEs, with a focus on elliptic, hyperbolic and certain degenerate hyperbolic PDE. For hyperbolic operators, this includes proving the Duistermaat-Hörmander theorem on the propagation of singularities. For certain degenerate hyperbolic operators, students will apply positive commutator methods to prove results on the propagation of microlocal regularity at critical or invariant sets for the Hamiltonian vector field of the principal symbol of the partial differential operator under study.

Content

Tempered distributions, Sobolev spaces, Schwartz kernel theorem.

Symbols, asymptotic summation.

Pseudodifferential operators on Euclidean space: composition, principal symbols and the symbol calculus, elliptic parametrix construction, boundedness on Sobolev spaces.

Pseudodifferential operators on manifolds, elliptic operators on compact manifolds and Fredholm theory, basic symplectic geometry.

Microlocalization: wave front set, characteristic set; pairings, products, restrictions of distributions.

Hyperbolic evolution equations: existence and uniqueness of solutions, Egorov's theorem.

Propagation of singularities: the Duistermaat-Hörmander theorem, microlocal estimates at radial sets.

Applications to general relativity: asymptotic behavior of waves on de Sitter space.

Lecture notes will be made available on the course website.

Lars Hörmander, "The Analysis of Linear Partial Differential Operators", Volumes I and III.

Alain Grigis and Johannes Sjöstrand, "Microlocal Analysis for differential operators: an introduction".

Prerequisites / notice

Students are expected to have a good understanding of functional analysis. Familiarity with distribution theory, the Fourier transform, and analysis on manifolds is useful but not strictly necessary; the relevant notions will be recalled in the course.

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies

Decision-making

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Customer Orientation

Domain D - Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

401-4657-00L Numerical Analysis of Stochastic Ordinary Differential Equations

W 6 credits 3V+1U A. Stein

Abstract

Course on numerical approximations of stochastic ordinary differential equations driven by Wiener processes. These equations have several applications, for example in financial option valuation. This course also contains an introduction to random number generation and Monte Carlo methods for random variables.

Objective

The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as financial mathematics. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content

Generation of random numbers

Monte Carlo methods for the numerical integration of random variables

Stochastic processes and Brownian motion

Stochastic ordinary differential equations (SODEs)

Numerical approximations of SODEs

Applications to computational finance: Option valuation

Lecture notes

There will be English, typed lecture notes for registered participants in the course.
Mathematical and Computational Methods in Photonics

Prerequisites:
Mandatory: Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.

a) mandatory courses:
Elementary Probability, Probability Theory I.

b) recommended courses:
Stochastic Processes.

The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces.

The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare.

The main objective in this course is to report on the use of sophisticated mathematics in diffractive optics, plasmonics, super-resolution, photonic crystals, and metamaterials for electromagnetic invisibility and cloaking. The book merges highly nontrivial multi-mathematics in order to make a breakthrough in the field of mathematical modelling, imaging, and optimal design of optical nanodevices and nanostructures capable of light enhancement, and of the focusing and guiding of light at a subwavelength scale. We demonstrate the power of layer potential techniques in solving challenging problems in photonics, when they are combined with asymptotic analysis and the elegant theory of Gohberg and Sigal on meromorphic operator-valued functions.

In this course we shall consider both analytical and computational matters in photonics. The issues we consider lead to the investigation of fundamental problems in various branches of mathematics. These include asymptotic analysis, spectral analysis, mathematical imaging, optimal design, stochastic modelling, and analysis of wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena.

An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

Prerequisites:
Familiarity of lattice models such as percolation or the Ising model can be useful but not necessary.

Abstract
This advanced course will be an introduction to SLE (Schramm-Loewner Evolutions), which are a class of conformally invariant random curves in the plane. We will discuss their construction and some of their main properties.

Ising Model

- Probability Theory.

Objective
The recent advances in nanoscience present great challenges for the applied and computational mathematics community. In nanophotonics, the aim is to control, manipulate, reshape, guide, and focus electromagnetic waves at nanometer length scales, beyond the resolution limit. In particular, one wants to break the resolution limit by reducing the focal spot and confine light to length scales that are significantly smaller than half the wavelength.

The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare.

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An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

Schramm-Loewner Evolutions

This advanced course will be an introduction to SLE (Schramm-Loewner Evolutions), which are a class of conformally invariant random curves in the plane. We will discuss their construction and some of their main properties.

Familiarity of lattice models such as percolation or the Ising model can be useful but not necessary.

Abstract

- Probability Theory.

Objective

Ising Model

- Probability Theory.

Objective

Schramm-Loewner Evolutions

This advanced course will be an introduction to SLE (Schramm-Loewner Evolutions), which are a class of conformally invariant random curves in the plane. We will discuss their construction and some of their main properties.

Familiarity of lattice models such as percolation or the Ising model can be useful but not necessary.

401-4785-00L

Mathematical and Computational Methods in Photonics

W 8 credits 4G H. Ammari

Abstract

The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces.

The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare.

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An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

Schramm-Loewner Evolutions

W 4 credits 2V W. Werner

Abstract

This advanced course will be an introduction to SLE (Schramm-Loewner Evolutions), which are a class of conformally invariant random curves in the plane. We will discuss their construction and some of their main properties.

Familiarity of lattice models such as percolation or the Ising model can be useful but not necessary.

Ising Model

W 4 credits 2V V. Tassion

Abstract

- Probability Theory.

Objective

Mathematics of Data Science

W 8 credits 4G A. Bandeira

Abstract

Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective

Introduction to various mathematical aspects of Data Science.

These topics lie in overlaps of (Applied) Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Each lecture will feature a couple of Mathematical Open Problem(s) related to Data Science. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Period</th>
<th>Instructor</th>
</tr>
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<tbody>
<tr>
<td>401-3621-00L</td>
<td>Fundamentals of Mathematical Statistics</td>
<td>W</td>
<td>10</td>
<td>S. van de Geer</td>
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<tr>
<td>401-3622-00L</td>
<td>Statistical Modelling</td>
<td>W</td>
<td>8</td>
<td>C. Heinze-Deml</td>
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<tr>
<td>401-4623-00L</td>
<td>Time Series Analysis</td>
<td>W</td>
<td>6</td>
<td>F. Balabdaoui</td>
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<td>401-3627-00L</td>
<td>High-Dimensional Statistics</td>
<td>W</td>
<td>4</td>
<td>P. L. Bühlmann</td>
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<tr>
<td>401-3612-00L</td>
<td>Stochastic Simulation</td>
<td>W</td>
<td>5</td>
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</tbody>
</table>
401-3628-14L Bayesian Statistics

**Abstract**
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

**Objective**
Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

**Content**
Topics that we will discuss are:
- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

**Lecture notes**
A script will be available in English.

**Literature**

**Prerequisites / notice**
Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

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401-4889-00L Mathematical Finance

**Abstract**
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

**Objective**
Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes)

**Content**
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.

Topics include:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

**Lecture notes**
The course is based on different parts from different books as well as on original research literature.

**Literature**
Lecture notes will not be available.

**Prerequisites / notice**
(Will be updated later)

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402-0861-00L Statistical Physics

**Abstract**
This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.

**Objective**
This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics education.

**Content**
Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions.

Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems.

Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons. Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state, phonons in elastic media and melting.

One-dimensional interacting systems.

Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order.


**Lecture notes**
Lecture notes available in English.

**Literature**
No specific book is used for the course. Relevant literature will be given in the course.
Objective
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

Content
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

Literature
Suggested textbooks:
- C. Misner, K. Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- R. Wald - General Relativity
- S. Weinberg - Gravitation and Cosmology

<table>
<thead>
<tr>
<th>Module Code</th>
<th>Module Name</th>
<th>Credits</th>
<th>Lecture Hours</th>
<th>Tutorial Hours</th>
<th>Taught in English</th>
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</thead>
<tbody>
<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>10</td>
<td>4V+2U</td>
<td>G. M. Graf</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity.

Topics include:
- Relativistic quantum mechanics
- Quantisation of bosonic and fermionic fields
- Interactions in perturbation theory
- Scattering processes and decays
- Elementary processes in QED
- Radiative corrections

Objective
The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.

Lecture notes
Will be provided as the course progresses

Taught competencies
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Analytical Competencies: assessed
- Domain B - Method-specific Competencies
  - Decision-making: not assessed
  - Problem-solving: assessed
- Domain C - Social Competencies
  - Communication: not assessed
  - Self-presentation and Social reflection: not assessed
- Domain D - Personal Competencies
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>402-0897-00L</td>
<td>Introduction to String Theory</td>
<td>6</td>
<td>2V+1U</td>
<td>J. Brödel</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

Objective
Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

Content
- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
- D-branes, T-duality
- supergravity as a low-energy effective theory, strings on curved backgrounds
- two-dimensional field theories (classical/quantum, conformal/non-conformal)

Literature
M.B. Green, J.H. Schwarz, E. Witten, Superstring Theory I, CUP (1987).

Prerequisites / notice
Recommended: Quantum Field Theory I (in parallel)
### 263-4500-00L Advanced Algorithms

**W** 9 credits  **ECTS** 3V+2U+3A  **M. Ghaffari, G. Zuzic**

**Abstract**
This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Objective**
This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

**Content**
The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

**Lecture notes**
https://people.inf.ethz.ch/gmohsen/AA21/

**Prerequisites / notice**
This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you’re ready for this class or not, please consult the instructor.

### 227-0447-00L Image Analysis and Computer Vision

**W** 6 credits  **ECTS** 3V+1U  **L. Van Gool, F. Konukoglu, F. Yu**

**Abstract**

**Objective**
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

**Content**
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

**Lecture notes**
Course material Script, computer demonstrations, exercises and problem solutions

**Prerequisites / notice**
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

### 227-0417-00L Information Theory I

**W** 6 credits  **ECTS** 4G  **A. Lapidoth**

**Abstract**
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

**Objective**
The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

**Content**
The entropy rate of a source. Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

**Literature**
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

### 227-0423-00L Neural Network Theory

**W** 4 credits  **ECTS** 2V+1U  **H. Bölcskei**

**Abstract**
The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

**Objective**
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

**Content**
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

**Lecture notes**
Detailed lecture notes are available on the course web page https://www.mins.ee.ethz.ch/teaching/nnnt/

**Prerequisites / notice**
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### 151-0563-01L Dynamic Programming and Optimal Control

**W** 4 credits  **ECTS** 2V+1U  **R. D'Andrea**

**Abstract**

**Objective**
Student Seminar in Symplectic vs. Contact Geometry

**Abstract**

This seminar provides a glimpse of two sister geometries that have recently earned a central role in mathematics interacting with other areas. Side by side, we will discuss basics of symplectic and contact manifolds, some key submanifolds (Lagrangian and Legendrian) and the toric subclasses (symplectic and contact), which have gained prominence as testing grounds for other theories.

**Objective**

By giving half-hour talks about each geometry, typing short notes for those talks and participating in talks by others, each participant will have the opportunity to get acquainted with the landscape of symplectic and contact worlds, expand their command of geometry and topology, and develop presentation and collaboration skills.

**Literature**

The Seminar webpage (under learning materials) contains a list of references and further information.

**Prerequisites / notice**

Prior knowledge of differential geometry and algebraic topology is required. Details of the seminar organization will be discussed in the first meeting.

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**Number of participants limited to 12.**

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Student Seminar in Probability

**Limited number of participants.**

Registration to the seminar will only be effective once confirmed by email from the organizers.

**Content**

The seminar is centered around a topic in probability theory which changes each semester. The student seminar in probability is held at times at the undergraduate level (typically during the spring semester) and at times at the graduate level (typically during the autumn term). The themes vary each semester.

**Prerequisites / notice**

Prior knowledge of differential geometry and algebraic topology is required. Details of the seminar organization will be discussed in the first meeting.

---

**Abstract**

This Student Seminar in Probability will be at an advanced level (dealing with current research topics), and the participants will be at a doctoral level or postdocs. Of course, non-participants are welcome to attend the various talks of the seminar.

---

**Number of participants limited to 12.**

---

**Abstract**

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### Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>401-5000-00L</td>
<td>Zurich Colloquium in Mathematics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>R. Abgrall, M. Iacobelli, A. Bandeira, A. Iozzi, S. Mishra,</td>
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<td>R. Pandharipande, University lecturers</td>
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<tr>
<td>401-5990-00L</td>
<td>Zurich Graduate Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>A. Iozzi, further speakers</td>
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<tr>
<td>Abstract</td>
<td>The Graduate Colloquium is an informal seminar</td>
<td></td>
<td></td>
<td></td>
<td>aimed at graduate students and postdocs whose purpose is to provide a</td>
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<td></td>
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<td>forum for communicating one's interests and thoughts in mathematics.</td>
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<td>401-4530-00L</td>
<td>Geometry Graduate Colloquium</td>
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<td>401-5110-00L</td>
<td>Number Theory Seminar</td>
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<td>401-5140-11L</td>
<td>Algebraic Geometry and Moduli Seminar</td>
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<td>2K</td>
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<td>401-5530-00L</td>
<td>Geometry Seminar</td>
<td>E-</td>
<td>0</td>
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<td>M. Burger, M. Einsiedler, P. Feller, A. Iozzi, U. Lang, University</td>
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<td>Abstract</td>
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<td>401-5350-00L</td>
<td>Analysis Seminar</td>
<td>E-</td>
<td>0</td>
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<td>A. Carlotto, F. Da Lio, A. Figalli, N. Hungerbühler, M. Iacobelli,</td>
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<td>401-5370-00L</td>
<td>Ergodic Theory and Dynamical Systems</td>
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<td>M. Akka Ginosar, M. Einsiedler, University lecturers</td>
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<td>401-5580-00L</td>
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<td>401-5650-00L</td>
<td>Zurich Colloquium in Applied and Computational</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>R. Abgrall, R. Aliafari, H. Ammari, R. Hiptmair, S. Mishra, S. Sauter</td>
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<tr>
<td>Mathematics</td>
<td>Research colloquium</td>
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<tr>
<td>401-5530-00L</td>
<td>Talks in Mathematical Physics</td>
<td>E-</td>
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<td>P. E. Y. Bousseau, A. Cattaneo, G. Felder, M. Gaberdiel, M. Graf, T. H.</td>
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<td>Willwacher</td>
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<td>Research colloquium</td>
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<tr>
<td>401-5600-00L</td>
<td>Seminar on Stochastic Processes</td>
<td>E-</td>
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<td>1K</td>
<td>J. Bertoin, A. Nikeghbali, B. D. Schlein, V. Tassion, W. Werner</td>
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<tr>
<td>401-5620-00L</td>
<td>Research Seminar on Statistics</td>
<td>E-</td>
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<td>P. L. Bühlmann, M. H. Maathuis, N. Meinshausen, S. van de Geer, A.</td>
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<td>Bandeira, R. Furrer, L. Held, T. Hothorn, D. Kozbur, M. Wolf</td>
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<td>Research colloquium</td>
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<tr>
<td>401-5680-00L</td>
<td>Foundations of Data Science Seminar</td>
<td>E-</td>
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<td>P. L. Bühlmann, A. Bandeira, H. Bölcskei, F. Yang</td>
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<td>Research colloquium</td>
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<td>Semester</td>
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<tr>
<td>401-5660-00L</td>
<td>DACO Seminar</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>A. Bandeira</td>
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<tr>
<td>401-5910-00L</td>
<td>Talks in Financial and Insurance Mathematics</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>B. Acciaio, P. Cheridito, D. Possamai, M. Schweizer, J. Teichmann, M. V. Wüthrich</td>
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<tr>
<td>401-5900-00L</td>
<td>Optimization Seminar</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>A. Bandeira, R. Weismantel, R. Zenklusen</td>
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<tr>
<td>252-4202-00L</td>
<td>Seminar in Theoretical Computer Science</td>
<td>E-</td>
<td>2</td>
<td>2S</td>
<td>E. Welzl, B. Gärtner, M. Ghaffari, M. Hoffmann, J. Lengler, A. Steger, D. Steurer, B. Sudakov</td>
</tr>
</tbody>
</table>

**Abstract**

Research colloquium

**Objective**

Lectures on current topics in optimization

**Content**

This seminar is a forum for researchers interested in optimization theory and its applications. Speakers are expected to stimulate discussions on theoretical and applied aspects of optimization and related subjects. The focus is on efficient algorithms for continuous and discrete optimization problems, complexity analysis of algorithms and associated decision problems, approximation algorithms, mathematical modeling and solution procedures for real-world optimization problems in science, engineering, industries, public sectors etc.

**Abstract**

Research colloquium

Regular research talks on various topics in mathematical finance and actuarial mathematics

**Objective**

Expose graduate students to ongoing research activities (including applications) in the domain of optimization.

**Content**

This seminar is a forum for researchers interested in optimization theory and its applications. Speakers are expected to stimulate discussions on theoretical and applied aspects of optimization and related subjects. The focus is on efficient algorithms for continuous and discrete optimization problems, complexity analysis of algorithms and associated decision problems, approximation algorithms, mathematical modeling and solution procedures for real-world optimization problems in science, engineering, industries, public sectors etc.

**Abstract**

Lectures on current topics in optimization

**Objective**

Lectures on current topics in optimization

**Content**

This seminar is a forum for researchers interested in optimization theory and its applications. Speakers are expected to stimulate discussions on theoretical and applied aspects of optimization and related subjects. The focus is on efficient algorithms for continuous and discrete optimization problems, complexity analysis of algorithms and associated decision problems, approximation algorithms, mathematical modeling and solution procedures for real-world optimization problems in science, engineering, industries, public sectors etc.

**Objective**

The goal is to introduce students to current research, and to enable them to read, understand, and present scientific papers.

**Prerequisite / notice**

This seminar takes place as part of the joint research seminar of several theory groups. Intended participation is for students with excellent performance only. Formal restriction is: prior successful participation in a master level seminar in theoretical computer science.

**Doctoral Department of Mathematics - Key for Type**

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

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

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# Doctoral and Post-Doctoral Courses

Please note that this is an INCOMPLETE list of courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0317-00L</td>
<td>Semiconductor Materials: Fundamentals and Fabrication</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>S. Schön, W. Wegscheider</td>
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<tr>
<td></td>
<td>Abstract: This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.</td>
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<td></td>
<td>Objective: Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing.</td>
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</tbody>
</table>
|                | Content: 1. Fundamentals of Solid State Physics  
|                | 1.1 Semiconductor materials  
|                | 1.2 Band structures  
|                | 1.3 Carrier statistics in intrinsic and doped semiconductors  
|                | 1.4 p-n junctions  
|                | 1.5 Low-dimensional structures  
|                | 2. Bulk Material growth of Semiconductors  
|                | 2.1 Czochalski method  
|                | 2.2 Floating zone method  
|                | 2.3 High pressure synthesis  
|                | 3. Semiconductor Epitaxy  
|                | 3.1 Fundamentals of Epitaxy  
|                | 3.2 Molecular Beam Epitaxy (MBE)  
|                | 3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)  
|                | 3.4 Liquid Phase Epitaxy (LPE)  
|                | 4. In situ characterization  
|                | 4.1 Pressure and temperature  
|                | 4.2 Reflectometry  
|                | 4.3 Ellipsometry and RAS  
|                | 4.4 LEED, AES, XPS  
|                | 4.5 STM, AFM  
|                | 5. The invention of the transistor - Christmas lecture |
|                | Lecture notes: https://moodle-app2.let.ethz.ch/course/view.php?id=15519 |
|                | Prerequisites / notice: The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture. |
| 402-0526-00L   | Ultrafast Processes in Solids                        | W    | 6 credits | 2V+1U | Y. M. Acremann |
|                | Abstract: Ultrafast processes in solids are of fundamental interest as well as relevant for modern technological applications. The dynamics of the lattice, the electron gas as well as the spin system of a solid are discussed. The focus is on time resolved experiments which provide insight into pico- and femtosecond dynamics. |
|                | Objective: After attending this course you understand the dynamics of essential excitation processes which occur in solids and you have an overview over state of the art experimental techniques used to study fast processes. |
|                | Content: 1. Experimental techniques, an overview  
|                | 2. Dynamics of the electron gas  
|                | 2.1 First experiments on electron dynamics and lattice heating  
|                | 2.2 The finite lifetime of excited states  
|                | 2.3 Detection of lifetime effects  
|                | 2.4 Dynamical properties of reactions and adsorbents  
|                | 3. Dynamics of the lattice  
|                | 3.1 Phonons  
|                | 3.2 Non-thermal melting  
|                | 4. Dynamics of the spin system  
|                | 4.1 Laser induced ultrafast demagnetization  
|                | 4.2 Ultrafast spin currents generated by lasers  
|                | 4.3 Landau-Lifschitz-Dynamics  
|                | 4.4 Laser induced switching  
|                | 5. Correlated materials |
|                | Lecture notes: will be distributed |
|                | Literature: relevant publications will be cited |
|                | Prerequisites / notice: The lecture can also be followed by interested non-physics students as basic concepts will be introduced. |
| 402-0464-00L   | Optical Properties of Semiconductors                 | W    | 8 credits | 2V+2U | J. Faist, P. Anantha Murthy |
|                | Abstract: This course presents a comprehensive discussion of optical processes in semiconductors. |
|                | Objective: The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these material, enabled numerous applications (lasers, LEDs and solar cells) as well as the realization of new physical concepts. Systems that will be covered include quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials. |
|                | Content: Electronic states in III-V materials and quantum structures, optical transitions, excitons and polaritons, novel two dimensional semiconductors, spin-orbit interaction and magneto-optics. |
|                | Prerequisites / notice: Quantum Mechanics I, Introduction to Solid State Physics |
| 402-0484-00L   | Experimental and Theoretical Aspects of Quantum Gases  | W    | 6 credits | 2V+1U | T. Esslinger |
|                | Abstract: Quantum Gases are the most precisely controlled many-body systems in physics. This provides a unique interface between theory and experiment, which allows addressing fundamental concepts and long-standing questions. This course lays the foundation for the understanding of current research in this vibrant field. |
Objective

The lecture conveys a basic understanding for the current research on quantum gases. Emphasis will be put on the connection between theory and experimental observation. It will enable students to read and understand publications in this field.

Content

Bose and Fermi gases

Ultracold collisions

The Bose-condensed state

Elementary excitations

Vortices

Superfluidity

Interference and Correlations

Lecture notes

notes and material accompanying the lecture will be provided

Literature


402-0553-00L Introduction to Magnetism

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>3G</th>
<th>A. Vindigni</th>
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</thead>
</table>

Abstract

Atomic paramagnetism and diamagnetism, itinerant and local-moment interatomic coupling, magnetic order at finite temperature, spin precession, approach to equilibrium through thermal and quantum dynamics, dipolar interaction in solids.

Objective

- Apply concepts of quantum-mechanics to estimate the strength of atomic magnetic moments and their interactions
- Identify the mechanisms from which exchange interaction originates in solids (itinerant and local-moment magnetism)
- Evaluate the consequences of the interplay between competing interactions and thermal energy
- Apply general concepts of statistical physics to determine the origin of bistability in realistic magnets
- Discriminate the dynamic responses of a magnet to different external stimuli

Content

The lecture "Introduction to Magnetism" is a regular course of the Physics MSc program and aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what "being magnetic" means is essential to address this question properly. Theoretical concepts will be applied to few selected nano-sized magnets, which will serve as clean reference systems.

At the end of this course students should have acquired the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Preliminary contents for the HS21:

- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field)
- Spin resonance and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)
- Magnetic order at finite temperatures (Ising and Heisenberg models, low-dimensional magnetism)
- Dipolar interaction in solids (shape anisotropy, dipolar frustration, origin of magnetic domains)

Lecture notes

Learning material will be made available through a dedicated RStudioServer and through Moodle.

Prerequisites / notice

Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism. Students will have the opportunity to self-assess their understanding through quizzes and interactive tutorials, mostly inspired by topics of current research in nanoscale magnetism.

402-0595-00L Semiconductor Nanostructures

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<tr>
<th>W</th>
<th>6 credits</th>
<th>2V+1U</th>
<th>T. M. Ihn</th>
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</table>

Abstract

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of quantum nanotransistors based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes


In addition to the lecture notes, the following supplementary books can be recommended:

The lecture is suitable for all physics students beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.

### Taught competencies

#### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: not assessed

#### Domain C - Social Competencies
- Communication: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed

#### Domain D - Personal Competencies
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: not assessed

### Prerequisites

**402-0715-00L Low Energy Particle Physics**

**W** 6 credits 2V+1U A. Soter, P. A. Schmidt-Wellenburg

**Abstract**

Low energy particle physics provides complementary information to high energy physics with colliders. In this lecture, we will concentrate on flagship experiments which have significantly improved our understanding of particle physics today, concentrating mainly on precision experiments with neutrons, muons and exotic atoms.

**Objective**

You will be able to present and discuss:
- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics

**Content**

Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrons and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:

- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
- various techniques: detectors, cryogenics, particle beams, laser cooling....

**Literature**

Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
- Rauch & Werner: "Neutron Interferometry"
- Carlile & Willis: "Experimental Neutron Scattering"
- Byrne: "Neutrons, Nuclei and Matter"
- Klapdor-Kleingrothaus: "Non Accelerator Particle Physics"

### 402-0767-00L Neutrino Physics

**W** 6 credits 2V+1U A. Rubbia, D. Sgalaberna

**Abstract**

Theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, interactions with leptons and quarks).

**Objective**

Introduction to the physics of neutrinos with special consideration of phenomena connected with neutrino masses.

**Lecture notes**


D.O. Caldwell, Current Aspects of Neutrino Physics, Springer.


**Literature**


### 376-1791-00L Introductory Course in Neuroscience I (University of Zurich)

**W** 2 credits 2V University lecturers

**Abstract**

The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

**Objective**

The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.
The lecture will treat the following chapters:

These lecture series will be dedicated to different advanced topics within the framework of theoretical cosmology and gravity. A detailed within this course, an introduction to the basics of string theory is provided. The seminar is aimed at all students who, during their studies, are confronted with age determination methods based on long-living radionuclides found in nature. Basic methodology, the latest developments, and special examples from a wide range of applications will be discussed.

The seminar provides the participants an overview about newest trends and developments of accelerator mass spectrometry (AMS) and related applications. In their talks and subsequent discussions the participants learn intensively about the newest trends in the field of AMS thus attaining a broad knowledge on both, the physical principles and the applications of AMS, which goes far beyond the horizon of their own studies.

The goal of this lecture is to explore both the rich physics as well as the application of these system for sources and detectors. In fact, devices based on intersubband transitions are now unlocking large area of the electromagnetic spectrum.

The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist, published by Oxford University Press.
Literature
Mostly the original articles, other useful reading can be found in:
- E. Rosencher and B. Vinter, Optoelectronics, Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

Prerequisites / notice
Requirements: A basic knowledge of solid-state physics and of quantum electronics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>University lecturers</th>
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<tbody>
<tr>
<td>402-0845-80L</td>
<td>Scattering Amplitudes in Quantum Field Theories</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>University lecturers</td>
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<td>Does not take place this semester. Special Students UZH must book the module PHY577 directly at UZH.</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>This course provides a pedagogical introduction to an advanced topic in Quantum Field Theories, which has undergone a tremendous progress in the new millennium: scattering amplitudes and on-shell methods.</td>
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<td><strong>Objective</strong></td>
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<td>Students that complete the course will be able to understand the basics of the modern methods to compute scattering amplitudes, to perform simple calculations and to read modern publications on this research field.</td>
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<td></td>
<td><strong>Content</strong></td>
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<td>This course covers the basic concepts of:</td>
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<td>- spinor helicity formalism</td>
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<td>- colour decompositions</td>
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<td>- BCFW on-shell recursion relations</td>
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<td>- BCJ colour-kinematics duality</td>
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<td>- Feynman integrals: IBPs and differential equations</td>
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<td>- analytic and algebraic structure of loop-level amplitudes:</td>
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<td>* Hopf algebras, symbols and coproducts</td>
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<td>* multiple polylogarithms (a.k.a. as iterated integrals on the Riemann sphere)</td>
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<td>* Steinmann relations</td>
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<td>* coaction principle</td>
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<td>* elliptic and modular-form integrals (a.k.a. as iterated integrals on the torus)</td>
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</table>

| Lecture notes | Will be provided at the Moodle site for the course. |
| Literature | Will be provided at the Moodle site for the course. |

Prerequisites / notice
A basic knowledge of Feynman rules in scalar field theories and in Yang-Mills theory is assumed.

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>University lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0845-61L</td>
<td>Effective Field Theories for Particle Physics</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Stoffer</td>
</tr>
<tr>
<td></td>
<td>Special Students UZH must book the module PHY578 directly at UZH.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The focus of the course is on Effective Field Theories (EFTs) and their interplay with dispersion theory. These topics will be discussed both in general terms and with specific phenomenological applications in the context of physics beyond the Standard Model, effective description of the weak interaction, as well as the description of non-perturbative strong interaction at low energies.</td>
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<td><strong>Objective</strong></td>
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<td>This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model. In the next part of the course, we will discuss Chiral Perturbation Theory (ChPT), the low-energy effective theory of Quantum Chromodynamics (QCD). We will briefly discuss the application of this concept to describe a class of theories beyond the SM in which the SM Higgs arises as a composite state of a new confining sector.</td>
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<td>The second focus of the course is on dispersion theory and its interplay with EFTs. We will discuss how to make use of the constraints from unitarity of the S-matrix and analyticity of scattering amplitudes, in order to extend the range of validity of the theoretical description compared to pure EFT methods. We will also discuss how to obtain constraints on EFT parameters from unitarity and analyticity. We will discuss the application of these methods both in the context of low-energy strong interaction and physics beyond the Standard Model.</td>
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<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>- Introduction to Effective Field Theories</td>
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<td>- Decoupling and matching</td>
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<td>- Renormalization group resummation</td>
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<td></td>
<td>- The Standard Model Effective Field Theory (SMEFT)</td>
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<td>- Chiral Lagrangians</td>
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<td></td>
<td>- Unitarity of the S-matrix</td>
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<tr>
<td></td>
<td>- Analyticity and dispersion relations</td>
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</tr>
</tbody>
</table>

| Prerequisites / notice | QFT-I (mandatory) and QFT-II (highly recommended) |

Prerequisites / notice
QFT-I and Introduction to Quantum ChromoDynamics are highly recommended.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Hours/Week</th>
<th>University lecturers</th>
</tr>
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<tbody>
<tr>
<td>402-0010-00L</td>
<td>Basics of Computing Environments for Scientists</td>
<td>Z</td>
<td>0</td>
<td></td>
<td>C. D. Herzog, C. Becker, S. Müller</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduce IT services at D-PHYS and offer modules covering IT-related topics for scientists.</td>
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</tbody>
</table>

Objective

The "IT at D-PHYS" introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department.

The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.

The "Linux Basics" modules offer an introduction to the Linux landscape and show how to work on the shell by using command line tools. The first part provides a basic understanding of Linux systems and their components. It introduces commands essential to working with local and remote machines. The second part focuses on more advanced tools and workflows and provides guidelines to scripting, automation and customization.

The "Python Ecosystem" modules present various aspects on the ecosystem around Python, without covering the programming language itself. The first part focuses on getting ready to run code. It discusses the management of Python interpreters, packages and virtual environments. The second part presents tools for writing code. From development environments (IDE, Jupyter), over code formatters and linters, to skimming selected concepts (string formatting, regular expressions).

The "System Aspects module" deals with the hardware-related side of scientific computing. To get the best performance out of your scientific code, you have to be aware of the underlying hardware and adapt to it.

Use the dedicated web page https://www.lehrbetrieb.ethz.ch/laborpraktika to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to https://compenv.phys.ethz.ch for the detailed contents.

Content

Introduction:

IT at D-PHYS (IT service providers and IT services at D-PHYS)

Modules:

- Linux Basics I (system components, basic shell usage)
- Linux Basics II (advanced tools, scripting)
- Python Ecosystem I (interpreters, packages, virtual environments)
- Python Ecosystem II (development environments, formatter and linter, string formatting, regexp)
- System Aspects (how the hardware affects your scientific code and vice versa)

Quantum Optics

Dr T. Esslinger

10 credits

3V+2U

Abstract

This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics and quantum computation.

Objective

The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.

Content

This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:

- coherence properties of light
- quantum nature of light: statistics and non-classical states of light
- light matter interaction: density matrix formalism and Bloch equations
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,
- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

Lecture notes

Selected book chapters will be distributed.

Literature

Text-books:

- G. Gryenberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
- R. Loudon, The Quantum Theory of Light
- Atomic Physics, Christopher J. Foot
- Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
- C. Cohen-Tannoudji et al., Atom-Photon-Interactions
- M. Scully and M.S. Zubairy, Quantum Optics
- Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

Doctoral Department of Physics - Key for Type

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

Key for Hours

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

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Doctoral Department of Environmental Sciences


Agricultural Sciences

Graduate Programme in Plant Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>751-4003-01L</td>
<td>Current Topics in Grassland Sciences (HS)</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>A. K. Gilgen</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as Ph.D. and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.</td>
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<tr>
<td>Objective</td>
<td>Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.</td>
<td></td>
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<tr>
<td>Content</td>
<td>Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as Ph.D. and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.</td>
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<tr>
<td>Lecture notes</td>
<td>none</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Basic knowledge of plant ecophysiology, terrestrial ecology and management of agro- and forest ecosystems. Course will be taught in English.</td>
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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-0205-00L</td>
<td>Challenges in Plant Sciences</td>
<td>W</td>
<td>2</td>
<td>2K</td>
<td>S. C. Zeeman, G. Dow, M. Paschke, B. Pfister, further lecturers</td>
</tr>
<tr>
<td>Number of participants limited to 40.</td>
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<tr>
<td>Abstract</td>
<td>The colloquium “Challenges in Plant Sciences” is a core class of the Zurich-Basel Plant Science Center’s PhD program and the MSc module. The colloquium introduces participants to the broad spectrum of plant sciences within the network. The course offers the opportunity to approach interdisciplinary topics in the field of plant sciences.</td>
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<tr>
<td>Objective</td>
<td>Objectives of the colloquium are:</td>
<td></td>
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<tr>
<td>Content</td>
<td>Introduction to recent research in all fields of plant sciences</td>
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<td></td>
<td>Working in interdisciplinary teams on the topics</td>
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<td></td>
<td>Developing presentation and discussion skills</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Self-direction and Self-management</td>
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</table>

Environmental Sciences

Atmosphere and Climate

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1239-00L</td>
<td>Aerosols I: Physical and Chemical Principles</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>M. Gysel Beer, D. Bell, E. Weingartner</td>
</tr>
<tr>
<td>Abstract</td>
<td>Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.</td>
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<tr>
<td>Objective</td>
<td>Physical and chemical principles:</td>
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<td></td>
<td>The students...</td>
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<td></td>
<td>- know the processes and physical laws of aerosol dynamics.</td>
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<td></td>
<td>- understand the thermodynamics of phase equilibria and chemical equilibria.</td>
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<td>- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.</td>
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<td>Experimental methods:</td>
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<td>The students...</td>
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<td>- know the most important chemical and physical measurement instruments.</td>
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<td></td>
<td>- understand the underlying chemistry and physics.</td>
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<td>Environmental impacts:</td>
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<td>The students...</td>
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<td>- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.</td>
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<td>- know the most important climate impacts of atmospheric aerosols.</td>
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<td>are aware of the health impacts of atmospheric aerosols.</td>
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<tr>
<td>Lecture notes</td>
<td>materiel is distributed during the lecture</td>
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</table>

This course will be designed as a reading course in 1-2 small groups of 8 students maximum. It will be based on the textbook below. The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Prerequisites / notice
Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.
The Lecture is composed of the following chapters:

Dynamics of large-scale atmospheric flow

This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Prerequisites / notice

Domain A - Subject-specific Competencies
- Concepts and Theories
- Domain C - Social Competencies
- Communication
- Domain D - Personal Competencies
- Critical Thinking
- Self-direction and Self-management

Taught competencies
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997
- Problemsolving
- Critical Thinking
- Communication
- Self-direction and Self-management

701-1221-00L Dynamics of Large-Scale Atmospheric Flow

Abstract
This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Objective
Understanding the dynamics of large-scale atmospheric flow

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites / notice

Domain B - Method-specific Competencies
- Analytical Competencies
-域 C - Social Competencies
- Communication
- Domain D - Personal Competencies
- Critical Thinking
- Self-direction and Self-management

701-1251-00L Land-Climate Dynamics

Abstract
The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy and water balances) in the climate system. The course consists of 2 contact hours per week, including lectures, group projects and computer exercises.

Objective
The students can understand the role of land processes and associated feedbacks in the climate system.

Content
- Historical review of the scientific research.
- Modelling of Solar UV radiation using satellite-based datasets.
- Methods to retrieve atmospheric constituents such as atmospheric ozone and aerosols from solar radiation measurements.
- Introduction to radiative transfer modelling, specifically for UV radiation.
- Measurements of solar UV radiation (ground-based, satellite-based).
- Variability of solar UV radiation from a solar perspective (solar cycle, solar UV variability, impact on the higher atmosphere).
- Understanding the variability of ground-based solar UV radiation with respect to the parameters influencing the transfer of solar UV radiation through the atmosphere.
- Instruments to measure solar UV radiation

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites / notice

Domain A - Subject-specific Competencies
- Concepts and Theories

Taught competencies
- Analytical Competencies
- Problem-solving
- Communication
- Critical Thinking
- Self-direction and Self-management

701-1237-00L Solar Ultraviolet Radiation

Abstract
The lecture will introduce the student to the thematic of solar ultraviolet radiation and its effects on the atmosphere and the biosphere, as well as the retrieval of atmospheric trace gases. The lecture will also cover the modeling and the measurement of solar ultraviolet radiation.

Objective
- Effects of solar UV radiation on the atmosphere, Humans, and the biosphere in general.
- Measurements of solar UV radiation (ground-based, satellite-based).
- Introduction to radiative transfer modelling, specifically for UV radiation.
- Methods to retrieve atmospheric constituents such as atmospheric ozone and aerosols from solar radiation measurements.
- Modelling of Solar UV radiation using satellite-based datasets.

Content
The Lecture is composed of the following chapters:
1) Introduction and Motivation on the impact of solar UV radiation on the atmosphere, humans, and the biosphere in general.
2) Historical review of the scientific research.
3) Variability of solar UV radiation from a solar perspective (solar cycle, solar UV variability, impact on the higher atmosphere).
4) Understanding the variability of ground-based solar UV radiation with respect to the parameters influencing the transfer of solar UV radiation through the atmosphere.
5) Introduction to radiative transfer modeling, with emphasis on solar UV radiation.
6) Instruments to measure solar UV radiation
7) Retrieval of atmospheric trace gases from solar radiation measurements. Specific examples for retrieving atmospheric ozone, aerosols, and surface albedo.
8) Solar UV modelling over Europe at high spatial resolution using satellite-based datasets.

Lecture notes
Lecture notes are based on the slides presented during the individual lectures. They will be handed out prior to the course via Moodle.

Literature
- Radiative transfer by S. Chandrasekhar,

Prerequisites / notice

Domain A - Subject-specific Competencies
- Basic mathematical concepts such as Integration of spectral quantities.
- Familiar with a mathematical package such as R, Matlab, Python is advantageous for the calculation of the exercises.

Domain B - Method-specific Competencies
- Analytical Competencies

Taught competencies
- Problem-solving
- Communication
- Critical Thinking
- Self-direction and Self-management

701-1221-00L Dynamics of Large-Scale Atmospheric Flow

W 1 credit

701-1251-00L Land-Climate Dynamics

W 3 credits

701-1237-00L Solar Ultraviolet Radiation

W 1 credit

Autumn Semester 2021

Page 663 of 2152
The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions. The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.

### Biogeochemistry and Pollutant Dynamics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1341-00L</td>
<td>Water Resources and Drinking Water</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Hug, M. Berg, F. Hammes, U. von Gunten</td>
</tr>
</tbody>
</table>

### Stratospheric Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1233-00L</td>
<td>Stratospheric Chemistry</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>T. Peter, G. Chiodo</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture gives an overview on the manifold reactions which occur in the gas phase, in stratospheric aerosol droplets and in polar cloud particles. The focus is on the chemistry of stratospheric ozone and its influence through natural and anthropogenic effects, especially the ozone depletion caused by CFCs in mid-latitude and polar regions as well as the coupling with the greenhouse effect.

**Objective**
The students will understand the gas phase reactions in the stratosphere as well as reactions and processes in aerosol droplets and polar stratospheric clouds.

**Content**
Short presentation of thermodynamical and kinetic basics of chemical reactions: bi- and termolecular reactions, photo-dissociation.

**Lecture notes**
Documents are provided in the contact hours.

**Literature**

**Prerequisites / notice**
Prerequisites: Basics in physical chemistry are required and an overview equivalent to the bachelor course in atmospheric chemistry (lecture 701-0471-01) is expected.

### Master’s Seminar: Atmosphere and Climate 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1211-01L</td>
<td>Master’s Seminar: Atmosphere and Climate 1</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield Könz, M. A. Wüest</td>
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</table>

**Abstract**
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other’s work.

**Objective**
Training scientific writing skills.

**Content**
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other’s work.

**Prerequisites / notice**
Attendance is mandatory.

### Colloquium Atmosphere and Climate 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

**Abstract**
The colloquium is a series of scientific talks by prominent invited speakers assembling interested students and researchers from around Zürich. Students take part of the scientific discussions.

**Objective**
The students are exposed to different atmospheric science topics and learn how to take part in scientific discussions.
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential and limitations and get familiar with important applications and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

Objective
The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.

Content
(ii) Definition, importance and biogeochemical classification of trace elements. (ii) Key biogeochemical processes controlling the cycling of different groups of trace elements. They are able to apply their knowledge on the interaction of trace elements with geosphere components and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

Literature
Handouts will be distributed every chapter

Prerequisites / notice
Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this course is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality. The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Content
The course introduces the scientific concepts and typical applications of tracers in biogeochemistry. The course covers stable and radioactive isotopes, geochemical tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles. The course provides essential theoretical background for the lab course "Isotopic and Organic Tracers Laboratory".

Literature
Selected handouts (lecture notes, literature, exercises) will be distributed during the course.

Prerequisites / notice
Students are expected to be familiar with the basic concepts of aquatic and soil chemistry covered in the respective classes at the bachelor level (soil mineralogy, soil organic matter, acid-base and redox reactions, complexation and sorption reactions, precipitation/dissolution reactions, thermodynamics, kinetics, carbonate buffer system).

Number of participants limited to 10

Abstract
Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content
From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Literature
None

Prerequisites / notice
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

Abstract
This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Objective
Ability to (1) understand the causes and consequences of water scarcity and water pollution problems in large international river systems; (2) understand ways and means of addressing such water challenges; and (3) analyse when and why international efforts in this respect succeed or fail.

Content
Based on lectures and discussion of scientific papers and reports, students acquire basic knowledge on contentious issues in managing international water resources, on the determinants of cooperation and conflict over international water issues, and on ways and means of mitigating conflict and promoting cooperation. Students will then, in small teams coached by the instructors, carry out research on a case of their choice (i.e., an international river basin where riparian countries are trying to find solutions to water allocation and/or water quality problems associated with a large dam project). They will write a brief paper and present their findings towards the end of the semester.
### Ecology and Evolution

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
--- | --- | --- | --- | --- | ---
701-0263-01L | Seminar in Evolutionary Ecology of Infectious Diseases | W | 3 credits | 2G | R. R. Regös, S. Bonhoeffer

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

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

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

**Lecture notes**
Powerpoint slides are available on the webpage. Additional documents are handed out as copies.

**Literature**
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

**Prerequisites / notice**
Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

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701-1453-00L | Ecological Assessment and Evaluation | W | 3 credits | 3G | F. Knaus

**Abstract**
The course provides methods and tools for ecological evaluations dealing with natural conservation or landscape planning. It covers census methods, ecological criteria, indicators, and critically appraises subjectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.

**Objective**
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation;
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

**Lecture notes**
Powerpoint slides are available on the webpage. Additional documents are handed out as copies.

**Literature**
Basic literature and references are listed on the webpage.

**Prerequisites / notice**
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

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701-1409-00L | Research Seminar: Ecological Genetics | W | 2 credits | 1S | S. Fior

**Abstract**
In this research seminar we will critically discuss recent publications on current topics in Ecological Genetics.

**Objective**
It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess and appreciate scientific publications in this field.

**Lecture notes**
none

**Literature**
Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course.

**Prerequisites / notice**
Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course.

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701-1425-01L | Genetic Diversity: Techniques | W | 2 credits | 4P | A. M. Minder Pfyl

**Waiting list will be deleted November 1st, 2021.**

**Abstract**
This course provides training for advanced students (master, doctoral or post-doctoral level) on how to measure and collect genetic diversity data from populations, experiments, field and laboratory. Different DNA/RNA extraction protocols, quality control measurements, SNP genotyping and gene expression techniques will be addressed.

**Objective**
To learn and improve on standard and modern methods of genetic data collection. Examples are: use of pyrosequencing, expression analysis, SNP-typing, next-generation sequencing etc. A course for practitioners.

**Content**
After an introduction (one afternoon), students will have 3 weeks to work independently in groups of two through different protocols. At the end the whole class meets for another afternoon to present the techniques/results and to discuss the advantages and disadvantages of the different techniques.

**Lecture notes**
Material will be handed out in the course.

**Literature**
Material will be handed out in the course.

**Prerequisites / notice**
Two afternoons are held in the class. The lab work will be done from the students according to their timetable, but has to be finished after 3 weeks. Effort is roughly 1-2 days per week, depending on the skills of the student.

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701-1676-01L | Genomics of Environmental Adaptation | W | 2 credits | 3G | R. Holderegger, F. Gugerli, C. Rellstab

**Waiting list will be deleted January 20th, 2022.**

**Prerequisites**
good knowledge in population genetics and some experience in using GIS and R is required.
Environmental Governance

This five-day winter school aims at teaching advanced Master students, PhD students and post-doctoral researchers on aspects of the genomics of environmental adaptation. It provides both theoretical background and hands-on exercises on major topics of contemporary environmental genomics such as signatures of selection, outlier analysis or environmental association analysis.

Topics:
1. How selection, drift, gene flow and isolation interact, affect neutral and adaptive genetic variation and influence the genetic structure of populations; genomic markers and next generation sequencing techniques.
2. Outlier analysis: concept and methodology of outlier analysis; diverse types of outlier analyses.
3. Environmental data: which environmental data are available and used to identify signatures of adaptation; what are their limitations; collinearity.
4. Environmental association analysis (landscape genomics): concept and types of environmental association analysis; genomic offset.
5. Genotypes and phenotypes: GWAS; follow-up analyses.

Lecture notes
Hand-outs will be distributed.

Handouts will be distributed.

Prerequisites / notice
Grading will be according to a written report (6-8 pages), in which students will have to design a complete study in environmental genomics, and according to student contributions during the course.

Prerequisites: students must have good knowledge in population genetics and evolutionary biology and basic skills in R; experience with GIS is advantageous.

551-0737-00L Ecology and Evolution: Interaction Seminar

Interaction seminar. Student-mediated presentations, guests and discussions on current themes in ecology, evolutionary and population biology.

Getting familiar with scientific arguments and discussions. Overview of current research topics. Making contacts with fellow students in other groups.

Scientific talks and discussions on changing subjects.

Lecture notes
None

Literature
None

Prerequisites / notice
For information, location and details: http://www.tb.ethz.ch/education/zis.html

Human-Environment Systems

Environmental Governance

The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

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

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.

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

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

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

Lecture notes
Lecture slides and additional course material will be provided on Moodle.

We will mostly work with readings from the following books:

Prerequisites / notice
A detailed course schedule will be made available at the beginning of the semester.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy).
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Decision-making</td>
<td>Cooperation and Teamwork</td>
<td>Critical Thinking</td>
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<td></td>
<td>Problem-solving</td>
<td>Self-presentation and Social Influence</td>
<td>Integrity and Work Ethics</td>
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<td>Project Management</td>
<td>Sensitivity to Diversity</td>
<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Negotiation</td>
<td>Self-direction and Self-management</td>
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</table>

### Abstract

Technological change plays a crucial role in efforts to create a more sustainable future. In this context, policy decision makers must design rules that minimize its risks and maximize its benefits for society at large. The course discusses this challenge from an interdisciplinary perspective taking into account legal, economic, historical, development and environmental aspects.

### Objective

- to recognize the challenges and opportunities of technological change in terms of sustainable development
- to become familiar with policy instruments to promote innovation
- to understand the interplay of politics and science and technology
- to improve understanding of the role of science and technology in the context of human and societal development

### Content

Science and Technology Policy is normally associated with the improvement of national competitiveness; yet, it is also an integral part of effective environmental and development policies.

The course will discuss the challenges and opportunities of technological change in terms of sustainable development and show how public policy on the national and the international level is responding to this challenge.

In this context, students are to become familiar with the basic principles of political economy and New Growth Theory and how such theories help explain political decisions as well as political outcomes in the area of Science, Technology and Innovation. State interventions are either designed to regulate (e.g. environmental regulations, anti-trust law) or facilitate (e.g. intellectual property rights protection, public investment in R&D and technical education, technology transfer) technological change. This will be illustrated by looking at different industries and different national systems of innovation. Subsequently the positive and negative consequences for society and the natural environment will be discussed from a short-term and a long-term perspective.

### Literature


Aerni, P. 2016a. Coping with Migration-Induced Urban Growth: Addressing the Blind Spot of UN Habitat. Sustainability 8(800), doi:10.3390/su808800


The 2-hour course (5-7 p.m.) will be held as a series of lectures. The course materials will be available in form of an electronic Reader at the beginning of the semester. The class will be taught in English. Students will be asked to make a contribution in class choosing one out of three options:
(a) presentation in class (15 Minutes) based on a paper to be discussed on a particular day in class
(b) review paper based on a selected publication in the course material
(c) preparation of questions for a selected invited speaker, and subsequent submission of protocol about the content of the talk and the discussion

In addition, they will have to pass a written test at the end of the course in order to obtain 3 credit points in the ECTS System. In the final mark (a) will have a weight of 40% and (b) 60%.

<table>
<thead>
<tr>
<th>701-1551-00L</th>
<th>Sustainability Assessment</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>P. Krüttli, D. Nef</th>
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<tbody>
<tr>
<td><strong>Number of participants limited to 35.</strong></td>
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<td>Waiting list will be deleted October 1st, 2021.</td>
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**Abstract**
The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

**Objective**
At the end of the course, students:
- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making

**Content**
The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

**Lecture notes**
Handouts are provided

**Literature**
Selected scientific articles and book-chapters

**Prerequisites / notice**
Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

**Taught competencies**
**Domain A - Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Domain C - Social Competencies**
- Communication
- Cooperation and Teamwork

**Domain D - Personal Competencies**
- Creative Thinking
- Critical Thinking

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**Forest and Landscape Management**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1615-00L</td>
<td>Advanced Forest Pathology</td>
<td>W</td>
<td>3</td>
<td>credits</td>
<td>2G</td>
</tr>
<tr>
<td>Abstract</td>
<td>In-depth understanding of concepts, insight into current research and experience with methods of Forest Pathology based on selected pathosystems.</td>
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<tr>
<td>Objective</td>
<td>To know current biological and ecological research on selected diseases, to be able to comment on it and to understand the methods. To understand the dynamics of selected pathosystems and disturbance processes. To be able to diagnose tree diseases and injuries. To know forest protection strategies and to be able to comment on them.</td>
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<tr>
<td>Content</td>
<td>Stress and disease, virulence and resistance, disease diagnosis and damage assessment, tree disease epidemiology, disease management, ecosystem pathology. Systems (examples): Air pollution and trees, endophytic fungi, mycorrhiza, wood decay, conifer- root rot, Phytophthora diseases, chestnut canker and its hypoviruses, urban trees, complex diseases, emerging diseases</td>
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<tr>
<td>Literature</td>
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<tr>
<td>Prerequisites / notice</td>
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</table>

| 701-1631-00L | Foundations of Ecosystem Management        | W    | 5    | credits | 3G | J. Ghazoul, C. Garcia, J. Garcia Ulloa, A. Giger Dray |
| Abstract    | This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake. |
| Objective   | Students should be able to
|             | a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales.
|             | b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management. |

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasize the functionality of human-dominated systems. Indeed, to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

Lecture notes
No Script

Literature

701-1651-00L
Environmental Governance W 6 credits 3G E. Lieberherr

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

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

Content
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

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

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

Lecture slides and additional course material will be provided on Moodle.

Lecture notes
Lecture slides and additional course material will be provided on Moodle.

We will mostly work with readings from the following books:

Prerequisites / notice
A detailed course schedule will be made available at the beginning of the semester.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) a three-years BSc education of a technical university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungsnationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy).

751-5125-00L

Number of participants limited to 25.
Abstract
This course provides an overview about the applicability of stable isotopes (carbon 13C, nitrogen 15N, oxygen 18O and hydrogen 2H) to process-oriented ecological research. Topics focus on stable isotopes as indicators for the origin of pools and fluxes, partitioning of composite fluxes as well as to trace and integrate processes. In addition, students carry out a small project during lab sessions.

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

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

Lecture notes
Handouts will be available on the webpage of the course.

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

<table>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit</th>
<th>Type</th>
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<tbody>
<tr>
<td>701-1065-00L</td>
<td>Earth Observation</td>
<td>4</td>
<td>W</td>
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<tr>
<td>701-1776-00L</td>
<td>Geographic Data Processing with Python and ArcGIS</td>
<td>1</td>
<td>2U</td>
</tr>
<tr>
<td>701-1868-00L</td>
<td>Dendroecology</td>
<td>3</td>
<td>3G</td>
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</tbody>
</table>

Abstract
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.

Objective
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation. Students should know at the end of the course:
1. Basics of measurement principle
2. Fundamentals of image acquisition
3. Basics of the sensor-specific geometries
4. Sensor-specific determination of environmental parameters

Content
• Die Lehrveranstaltung gibt einen Einblick in die heutige Erdbeobachtung mit dem folgenden skizzierten Inhalt:
  1. Einführung in die Fernerkundung von Luft- und Weltraum gestützten Systemen
  2. Einführung in das Elektromagnetische Spektrum
  3. Einführung in optische Systeme (optisch und hyperspektral)
  4. Einführung in Mikrowellen-Technik (aktiv und passiv)
  5. Einführung in atmosphärische Systeme (meteo und chemisch)
  6. Einführung in die Techniken und Methoden zur Bestimmung von Umweltparametern
  7. Einführung in die Anwendungen zur Bestimmung von Umweltparametern in der Hydrologie, Glaziologie, Forst und Landwirtschaft, Geologie und Topographie

Lecture notes
Foliens zu jeden Vorlesungsblock werden zur Verfügung gestellt.

Literature
Ausgewählte Literatur wird am Anfang der Vorlesung vorgestellt.

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>701-1776-00L</td>
<td>Geographic Data Processing with Python and ArcGIS</td>
<td>1</td>
<td>2U</td>
</tr>
</tbody>
</table>

Abstract
The course communicates the basics of the programming language Python and gives a general introduction into the geoprocessing framework of ArcGIS. In addition various Python libraries (numpy, Scipy, GDAL, statsmodels, pandas, Jupyter Notebook) will be introduced which increase the functional range of the geoprocessing framework substantially.

Objective
The students learn the basics of geographic data processing based on the programming language Python and ArcGIS (arcpy). They get the ability to implement their own processing sequences and models for geoprocessing. The students are able to integrate open source libraries in their Python scripts and know how the libraries are applied to spatial datasets.

Content
The course communicates a deepened understanding of the geoprocessing frameworks arcpy and covers basic language concepts of Python such as datatypes, control structures and functions. In addition the application of popular Python libraries in combination with spatial datasets will be shown.

Lecture notes
Lecture notes, exercises and worked out solutions to them will be provided.

Literature

Prerequisites / notice
Basic knowledge of ArcGIS is assumed.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1868-00L</td>
<td>Dendroecology</td>
<td>3</td>
<td>3G</td>
</tr>
</tbody>
</table>

Abstract
The course dendroecology offers theoretical and practical aspects of dendrochronology. The impact of different environmental influences on tree-ring characteristics will be shown. The students learn various methods to date tree rings and they understand how ecological and environmental processes and patterns can be reconstructed using tree rings.

Objective
The students...
- understand, how wood is configured and how tree-ring structures are formed.
- are able to identify and describe different tree-ring structures.
- understand the theoretical and practical aspects of the dating of tree rings.
- know the effects of different abiotic and biotic environmental influences (climate, site, competition, insects, fire, physical-mechanical influences) on trees and tree rings.
- discover a tool for understanding and reconstructing global change processes.
- learn software to date, standardize and analyze tree rings.
- get hands-on experience based on the demonstration of wood (increment cores, stem discs, wedges), sampling in the field, and measuring and dating of tree rings in the tree-ring lab.
- solve R-based exercises (R tutorial will be provided) and answer questions in Moodle.
- work on an independent research question related to a dendroecological topic and write a short literature review based on scientific papers.

Content
- Overview and history of dendrochronology
- Principles of dendrochronology
- Formation and structure of wood and tree rings
- Wood anatomy and intra-seasonal tree-ring growth
- Continuous and discontinuous tree-ring characteristics
- Sampling and measuring of tree rings
- Crossdating methods (visual, skeleton plots, quantitative)
- Detrending and standardization of tree-ring series
- Development of tree-ring chronologies
- Water transport in trees
- Stable isotopes in tree rings
- Climate influences, climate-growth relationships, climate reconstructions
- Reconstruction of forest dynamics (regeneration, growth, competition, mortality)
- Disturbance ecology (fire, insects, blowdown)
- Application of tree-ring research in practice and in interdisciplinary research projects
- Field and lab day (date for one entire day or two half days will be searched together with the students in the beginning of the semester): discussion of different dendroecological questions in the forest: sampling of trees; insight into different tree-ring projects in the lab (Swiss Federal Institute for Forest, Snow and Landscape Research WSL)

Lecture notes
Lecture notes (in English) will be handed out in the class.

Literature
Literature lists will be handed out in the class.

Prerequisites / notice
Time schedule (total of 90 hours): There will be 12 lectures with each two hours (total of 24 hours presence) as well as a field and lab day (8 hours presence). In addition, the students are expected to put 18 hours into the preparation of the lectures as well as 18 hours for the exercises. 4 hours are reserved for the lab work and 18 hours for the project.

The class language is German and English, on request English only.

Requirements:
- Basics of biology, ecology and forest ecology

701-1695-00L Soil Science Seminar Z 0 credits 1S R. Kretzschmar, A. Carminati, S. Dötterl, E. Frossard, M. Hartmann

Abstract
Invited external speakers present their research on current issues in the field of soil science and discuss their results with the participants.

Objective
Master and PhD students are introduced to current areas of research in soil sciences and get first-hand experience in scientific discussion.

Inter- and Transdisciplinary Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0015-00L</td>
<td>Transdisciplinary Research: Challenges of Interdisciplinarity and Stakeholder Engagement</td>
<td>W</td>
<td>2</td>
<td>2</td>
<td>M. Stauffacher, C. E. Pohl, B. Vienni Baptista</td>
</tr>
</tbody>
</table>

All participants will be on the waiting list at first. Enrollment is possible until 15 September 2021. The waiting list is active until 17 September. All students will be informed on 19 September, if they can participate in the lecture. The lecture takes place if a minimum of 12 students register for it.

Abstract
This seminar is designed for PhD students and PostDoc researchers involved in inter- or transdisciplinary research. It addresses and discusses challenges of this kind of research using scientific literature presenting case studies, concepts, theories, methods and by testing practical tools. It concludes with a 10-step approach to make participants’ research projects more societally relevant.

Objective
Participants know specific challenges of inter- and transdisciplinary research and can address them by applying practical tools. They can tackle questions like: how to integrate knowledge from different disciplines, how to engage with societal actors, how to secure broader impact of research? They learn to critically reflect their own research project in its societal context and on their role as scientists.

Content
The seminar covers the following topics:
(1) Theories and concepts of inter- and transdisciplinary research
(2) The specific challenges of inter- and transdisciplinary research
(3) Collaborating between different disciplines
(4) Engaging with stakeholders
(5) 10 steps to make participants’ research projects more societally relevant

Throughout the whole course, scientific literature will be read and discussed as well as practical tools explored in class to address concrete challenges.

Literature
Literature will be made available to the participants.
Further, this collection of tools will be used
https://naturalsciences.ch/topics/co-producing_knowledge

Prerequisites / notice
Participation in the course requires participants to be working on their own research project.
Dates (Wednesdays, 8h15-12h00): 29 September, 27 October, 10 November, 24 November, 8 December

Basic and Scientific Skills

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0019-00L</td>
<td>Readings in Environmental Thinking</td>
<td>W</td>
<td>3</td>
<td>2</td>
<td>J. Ghazoul</td>
</tr>
</tbody>
</table>

This course introduces students to foundational texts that led to the emergence of the environment as a subject of scientific importance, and shaped its relevance to society. Above all, the course seeks to give confidence and raise enthusiasm among students to read more widely around the broad subject of environmental sciences and management both during the course and beyond.
Objectives

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different participants of the course Research Ethics will.

Content

The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The lecturer will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:

- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

Prerequisites

- HS
- Bachelor degree

Literature

The specific texts selected for discussion will vary, but examples include:

- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Lovelock (1979) Gaia: A New look at life on Earth
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

701-3001-00L Environmental Systems Data Science W 3 credits 2G L. Pellissier, J. Payne, B. Stocker

Abstract

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

Objective

The students are able to:

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

Content

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

Prerequisites / notice

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

851-0180-00L Research Ethics W 2 credits 2G G. Achermann, P. Emch

Number of participants limited to 40

Abstract

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective

Participants of the course Research Ethics will:

- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;
I. Introduction to Moral Reasoning

1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in "Research Ethics"

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a "right" answer?

II. Research Ethics - Internal responsibilities

1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities

1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements? First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

Additional Courses

Course Catalogue of ETH Zurich

Doctoral Department of Environmental Sciences - Key for Type

<table>
<thead>
<tr>
<th>Dr</th>
<th>Suitable for doctorate</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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</table>

<table>
<thead>
<tr>
<th>W</th>
<th>Eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Key for Hours</td>
<td>( \text{ECTS} )</td>
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<td>--------------</td>
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</tr>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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Electrical Engineering and Information Technology Bachelor

1st Semester

First Year Examinations

First Year Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0003-00L</td>
<td>Digital Circuits</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Luisier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Digital and analogue signals and their representation, logic gates, transistors, combinational and sequential circuits and systems, boolean algebra, Karnaugh-maps, finite state machines, memory and computing building blocks in CMOS technology.</td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>Provide basic knowledge and methods to understand and to design digital circuits and systems.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Digital and analogue signals and their representation. Boolean Algebra, circuit analysis and synthesis, the MOS transistor, CMOS logic, static and dynamic behaviour, Karnaugh-Maps, hazards, binary number systems, coding. Combinational and sequential circuits and systems (boolean algebra, K-maps, etc.). Memory building blocks and memory structures, programmable logic circuits. Finite state machines, architecture of microprocessors.</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes for all lessons, assignments and solutions.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Literature will be announced during the lessons.</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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</tr>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
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<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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</tr>
</tbody>
</table>

| 401-0151-00L | Linear Algebra             | O    | 5 credits | 3V+2U    | V. C. Gradinaru |
| Abstract | Contents: Linear systems - the Gaussian algorithm, matrices - LU decomposition, determinants, vector spaces, least squares - QR decomposition, linear maps, eigenvalue problem, normal forms - singular value decomposition; numerical aspects; introduction to MATLAB. |       |       |           |               |
| Objective | Einführung in die Lineare Algebra für Ingenieure unter Berücksichtigung numerischer Aspekte |       |       |           |               |
| Lecture notes | eigenes Aufschrieb und K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002 |       |       |           |               |
| Literature | K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002 |       |       |           |               |
| Taught competencies | Domain A - Subject-specific Competencies | Concepts and Theories | assessed |         |               |
|                     | Domain B - Method-specific Competencies | Analytical Competencies | assessed |         |               |
|                     | Domain C - Social Competencies | Communication | not assessed |         |               |
|                     | Domain D - Personal Competencies | Creative Thinking | assessed |         |               |

| 227-0001-00L | Networks and Circuits I   | O    | 4 credits | 2V+2U    | C. Franck   |
| Abstract | This course introduces the students into the basics of electric circuits, the underlying physical phenomena and required mathematical methods. |       |       |           |               |
| Objective | Voltage, current and properties of basic elements of electric circuits, i.e. capacitors, resistors and inductors should be understood in relation to electric and magnetic fields. Furthermore, the students should be able to mathematically describe, analyze and finally design technical realizations of circuit elements. Students should also be familiar with the calculation of voltage and current distributions of DC circuits. The effect and the mathematical formulation of magnetic induction should be known for technical applications. |       |       |           |               |
| Content  | Electrostatic field; Stationary electric current flow; Basic electric circuits; current conduction mechanisms; time variant electromagnetic field. |       |       |           |               |
| Lecture notes | Manfred Albach, Elekrotechnik ISBN 978-3-86894-398-6 (2020) and lecture notes |       |       |           |               |
| Literature | Manfred Albach, Elekrotechnik 978-3-86894-398-6 (2020) |       |       |           |               |
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies not assessed
- Decision-making not assessed
- Media and Digital Technologies not assessed
- Problem-solving not assessed

Domain C - Social Competencies
- Communication not assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility not assessed
- Creative Thinking not assessed
- Critical Thinking not assessed
- Integrity and Work Ethics not assessed
- Problem-solving not assessed
- Project Management not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

151-0223-10L Engineering Mechanics
- 4 credits
- 2V+2U+1K
- P. Tiso

Abstract
Introduction to engineering mechanics: kinematics, statics and dynamics of rigid bodies and systems of rigid bodies.

Objective
Students can solve problems of elementary engineering mechanics.

Content
Basic notions: position and velocity of particles, rigid bodies, planar motion, kinematics of rigid body, force, couple, power.
Statics: static equivalence, force-couple system, center of forces, centroid, principle of virtual power, equilibrium, constraints, statics, traction.
Dynamics: acceleration, inertial forces, d'Alembert's Principle, Newton's Second Law, principles of linear and angular momentum, equations of planar motion of rigid bodies.

Lecture notes
yes, in German

Literature

First Year Examination Block B

Number Title Type ECTS Hours Lecturers
401-0231-10L Analysis 1 O 8 credits 4V+3U T. Rivière

Abstract
Reelle und komplexe Zahlen, Grenzwerte, Folgen, Reihen, Potenzreihen, stetige Abbildungen, Differential- und Integralrechnung einer Variablen, Einführung in gewöhnliche Differentialgleichungen

Objective
Einführung in die Grundlagen der Analysis

Lecture notes
Christian Blatter: Ingenieur-Analysis (Kapitel 1-4)

Literature
Konrad Koenigsberger, Analysis I.
Christian Blatter, Analysis I.

First Year Compulsory Laboratory Courses

Number Title Type ECTS Hours Lecturers
227-0005-10L Digital Circuits Laboratory O 1 credit 1P A. Emboras, M. Lusier

Abstract
Digital and analogue signals and their representation. Combinational and sequential circuits and systems, boolean algebra, Karnaugh-maps. Finite state machines. Memory and computing building blocks in CMOS technology, programmable logic circuits.

Objective
Deepen and extend the knowledge from lecture and exercises, usage of design software Quartus II as well as an oscilloscope

Content
The contents of the digital circuits laboratory will deepen and extend the knowledge of the correspondent lecture and exercises. With the help of the logic device design software Quartus II different circuits will be designed and then tested on an evaluation board. You will build up the control for a 7-digit display as well as an adder and you will create different types of latches and flip-flops. At the end of the laboratory a small synthesizer will be programmed that is able to play self-created melodies. At the same time the usage of a modern oscilloscope will be taught in order to analyse the programmed circuits through the digital and analogue inputs.

Lecture notes
Lecture notes for all experiments.
https://iis-students.ee.ethz.ch/lectures/digital-circuits/praktikum/

Prerequisites / notice
No special prerequisites

Autumn Semester 2021
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed

Abstract

The course provides an elementary introduction to programming with C++. Prior programming experience is not required.

Objective

Establish an understanding of basic concepts of imperative programming and how to systematically approach programming problems. Students are able to read and write simple C++ programs.

Content

This course introduces you to the basics of programming with C++. Programming means instructing a computer to execute a series of commands that ultimately solve a particular problem.

The course comprises the following:
- General introduction to computer science: development, goals, fundamental concepts
- Interactive self-study tutorial that provides an introduction to C++ and covers the following topics: variables, data types, conditional statements and loops
- Introduction to stepwise refinement as an approach to systematically solving programming problems
- Two small programming projects, to practically apply the studied fundamentals

Lecture notes

All teaching material is available online; an online development environment is used for the the programmig projects.

3rd Semester: Examination Blocks

Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-0353-00L</td>
<td>Analysis 3</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Iacobelli</td>
</tr>
</tbody>
</table>

Abstract

In this lecture we treat problems in applied analysis. The focus lies on the solution of quasilinear first order PDEs with the method of characteristics, and on the study of three fundamental types of partial differential equations of second order: the Laplace equation, the heat equation, and the wave equation.

Objective

The aim of this class is to provide students with a general overview of first and second order PDEs, and teach them how to solve some of these equations using characteristics and/or separation of variables.

Content

1.) General introduction to PDEs and their classification (linear, quasilinear, semilinear, nonlinear / elliptic, parabolic, hyperbolic)

2.) Quasilinear first order PDEs
   - Solution with the method of characteristics
   - Conservation laws

3.) Hyperbolic PDEs
   - wave equation
   - d'Alembert formula in (1+1)-dimensions
   - method of separation of variables

4.) Parabolic PDEs
   - heat equation
   - maximum principle
   - method of separation of variables

5.) Elliptic PDEs
   - Laplace equation
   - maximum principle
   - method of separation of variables
   - variational method

Literature


Prerequisites / notice

Prerequisites: Analysis I and II, Fourier series (Complex Analysis)

Exam 2021 Autumn Semester 2021
The course provides the foundations for the design and analysis of algorithms.

Abstract

The course comprises an introduction to parallel and concurrent programming.

Objective

The course also comprises an introduction to parallel and concurrent programming.

Content

The course is a prerequisite for higher semester subjects such as analog integrated circuits, RF circuits for wireless communications, A/D and D/A converters and optoelectronics.

Prerequisites / notice

The concepts are underpinning with examples of concurrent and parallel programs and with parallel algorithms, implemented in C++.

The relationship and tight coupling between algorithms and data structures is illustrated with graph algorithms (traversals, topological sort, closure, shortest paths, minimum spanning trees).

The concepts provided in the course are motivated and illustrated with practically relevant algorithms and applications.

Exercises are carried out in Code-Expert, an online IDE and exercise management system.

All required mathematical tools above high school level are covered, including an introduction to graph theory.

Lecture notes

Lecture notes, problem set with solutions.

Literature

Lecture notes (hand-written) will be distributed via the Moodle interface.


Prerequisites: Physics I.

227-0045-00L Signals and Systems I

Abstract


Objective

Introduction to mathematical signal processing and system theory.

Content


Lecture notes

Lecture notes, problem set with solutions.

252-0836-00L Computer Science II

Abstract

The course provides the foundations for the design and analysis of algorithms. Classical problems ranging from sorting up to problems on graphs are used to discuss common data structures, algorithms and algorithm design paradigms.

The course also comprises an introduction to parallel and concurrent programming.

Objective

An understanding of the analysis and design of fundamental and common algorithms and data structures. Knowledge regarding chances, problems and limits of the serial and concurrent programming.

Content

Data structures and algorithms: mathematical tools for the analysis of algorithms (asymptotic function growth, recurrence equations, recurrence trees), informal proofs of algorithm correctness (invariants and code transformation), design paradigms for the development of algorithms (induction, divide-and-conquer, backtracking and dynamic programming), classical algorithmic problems (searching, selection and sorting), data structures for different purposes (linked lists, hash tables, balanced search trees, heaps, union-find), further tools for runtime analysis (generating functions, amortized analysis). The relationship and tight coupling between algorithms and data structures is illustrated with graph algorithms (traversals, topological sort, closure, shortest paths, minimum spanning trees).

Parallel programming: structure of parallel architectures (multicore, vectorization, pipelining) concepts of parallel programming (Amdahl's and Gustavson's laws, task/dataset parallelism, scheduling), problems of concurrency (data races, bad interleavings, memory reordering), process synchronisation and communication in a shared memory system (mutual exclusion, semaphores, monitors, condition variables). The concepts are underpinning with examples of concurrent and parallel programs and with parallel algorithms, implemented in C++.

In general, the concepts provided in the course are motivated and illustrated with practically relevant algorithms and applications.

Exercises are carried out in Code-Expert, an online IDE and exercise management system.

All required mathematical tools above high school level are covered, including an introduction to graph theory.

Lecture notes

tba

Literature


Prerequisites / notice

Prerequisite: Computer Science I

★★★ Examination Block 2

Examination Block 2

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
227-0077-10L | Electronic Circuits | O | 4 credits | 2V+2U | T. Burger

Abstract

Introductory lecture on electronic circuits. Transistor fundamentals, analysis and design of transistor based electronic circuits such as amplifiers and filters; operational amplifiers and circuits based thereon.

Objective

Modern, transistor-based electronics has transformed our lives and plays a crucial role in our economy since the 2nd half of last century. The main objective of this course in electronic circuits is to introduce the concept of the active device, including operational amplifiers, and their use in amplification, signal conditioning, switching and filtering to students. In addition to gaining experience with typical electronic circuits that are found in common applications, including their own Gruppenarbeit and Fachpraktikum projects, students sharpen their understanding of linear circuits based on nonlinear devices, imperfections of electronic circuits and the concept of design (as opposed to analysis). The course is a prerequisite for higher semester subjects such as analog integrated circuits, RF circuits for wireless communications, A/D and D/A converters and optoelectronics.

Content


Modern, transistor-based electronics has transformed our lives and plays a crucial role in our economy since the 2nd half of last century. The main objective of this course in electronic circuits is to introduce the concept of active device, including operational amplifiers, and their use in amplification, signal conditioning, switching and filtering to students. In addition to gaining experience with typical electronic circuits that are found in common applications, including their own Gruppenarbeit and Fachpraktikum projects, students sharpen their understanding of linear circuits based on nonlinear devices, imperfections of electronic circuits and the concept of design (as opposed to analysis). The course is a prerequisite for higher semester subjects such as analog integrated circuits, RF circuits for wireless communications, A/D and D/A converters and optoelectronics.

Get to know and understand basic transistor and op amp based electronic circuits. Build and operate simple electronic circuits including supply decoupling. Carry out and understand different, principal measurement methods such as DC- and AC-analysis, time and frequency domain measurements, impedance and transfer function measurements. In the lab we will have a closer look at the following topics and circuits: characterization of a real capacitor including non-idealities; common-emitter transistor amplifier with emitter degeneration; characterization of a real operational amplifier with non-idealities; band pass filter with op amp, resistors and capacitors; data converters; oscillator and function generator based on an op amp.

A minimum of 18 cp (under the 2016 regulations), respectively at least 15 cp (under the 2018 regulations) must be achieved in the category "Laboratory Courses, Projects, Seminars".

Enrolment via Online-Tool (EE-Website: Studies -> Bachelor Program -> Third Year -> Laboratory Courses)

The Laboratory courses in the 5th and 6th semesters enable the students to put to the tests the contents of the courses from the four first semesters to the test and to consolidate the acquired knowledge. Furthermore students have the possibility to gain specific knowledge in certain software packages as MATLAB.


Enrolment is only possible for students in the BSc Electrical Engineering and Information Technology from Friday before the start of the semester. Please only enrol for P&S for which you apply via the tool.

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
**Objective**

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Abstract**

Simulation tools are becoming an essential accessory for scientists and engineers for the development of new devices and study of physical phenomena. More and more disciplines rely on accurate simulation tools to get insight and also to accurately design novel devices.

**Objective**

Game Development is a big field and is constantly growing. A powerful tool to create cross-platform games is Unity. Unity is a cross-platform real-time game engine that uses C# as its programming language (very similar to Java). This P&S is a great chance for gaining practical experience, creating something from scratch and establishing a supporting community. Therefore, if you are eager to improve your coding skills as well as bring them to life by applying them to game development, this is the right P&S for you!

**Prerequisites / notice**

No previous knowledge of simulation tools is required. A basic understanding of electromagnetics is helpful but not mandatory.

The course will be taught in English.

**Projects & Seminars: COMSOL Design Tool – Design of Optical Components**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Projects & Seminars: Microcontrollers for Sensors and Internet of Things**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Projects & Seminars: Fast Signal Acquisition and Processing for Quantum Experiments Using FPGA**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.
FPGAs are used in a wide range of applications including video processing, machine learning, cryptography, and radar signal processing. Thanks to their flexibility and massive parallel processing power, FPGAs have become important in quantum signal processing. In recent years, FPGAs have been used in various domains such as computer vision, cryptography, and machine learning. These technologies allow for the implementation of complex algorithms in hardware, providing high performance and energy efficiency.

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allowing for explorative learning and the methodology of project work.

Projects & Seminars: Neural Network on Low Power
FPGA: A Practical Approach

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allowing for explorative learning and the methodology of project work.

Objective
FPGAs are used in a wide range of applications including video processing, machine learning, cryptography, and radar signal processing. Recently FPGAs have become important in quantum signal processing where high amounts of data should be analyzed in a short time to use quantum setups most efficiently. In addition, FPGAs are used for quantum state detection and feedback generation, which have to be performed in the scale of hundreds of nanoseconds. The goal of this course is to understand the FPGA based signal processing for superconducting circuits based quantum experiments. The course participants will learn the implementation techniques of the modules for fast quantum signal acquisition and processing, the electronics supporting quantum experiments, and FPGA programming. You will implement quantum signal processing and quantum state detection modules using Xilinx FPGA, Verilog HDL, and high speed ADC. The course will be taught in English. No prior knowledge in quantum physics or FPGA is required, still a good knowledge in any coding language (for example C or Java) is required.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Projects & Seminars: Deep Learning for Smartphone
Apps (DLSA)

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allowing for explorative learning and the methodology of project work.

Objective
Artificial Intelligence and in particular neural networks are inspired by biological systems, such as the human brain. Through the combination of powerful computing resources and novel architectures for neurons, neural networks have achieved state-of-the-art results in many domains such as computer vision. FPGAs are one of the most powerful platforms to implement neural networks as they can handle different algorithms in computing, logic, and memory resources in the same device. Faster performance comparing to competitive implementations as the user can hardcore operations into the hardware. This course will give to the student the basis of Machine Learning to understand how they work and how they can be trained and giving hand-on experiences with the training tools such as Keras. Moreover, the course will focus in deploy algorithms in low power FPGA such as the Lattice sensAI platform to have energy efficient running algorithms. The course will provide to the students the tools and know-how to implement neural network on an FPGA, and the student will challenge theirselves in a 5 weeks practical project that they will present at the end of the course. Experience in FPGA programming is desirable but not mandatory.

The course will be taught in English.

Projects & Seminars: Bluetooth Low Energy
Programming for IoT Sensing System

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allowing for explorative learning and the methodology of project work.

Objective
The course will focus in deploy algorithms in low power FPGA such as the Lattice sensAI platform to have energy efficient running algorithms. The course will provide to the students the tools and know-how to implement neural network on an FPGA, and the student will challenge theirselves in a 5 weeks practical project that they will present at the end of the course. Experience in FPGA programming is desirable but not mandatory.

The course will be taught in English.
Objective

Bluetooth Low Energy System on Chip – Firmware Programming and sensors Interfacing using an Arm Cortex-M (Nordic nrf52838) Microcontroller

With the introduction of the BLE 5.0 standard, Bluetooth has achieved high data bandwidth with low power consumption. This makes the technology an ideal match for many applications, i.e., IoT sensor application or audio streaming, by addressing two of the greatest bottlenecks of these devices. This course offers the chance for participants to do hands-on programming of microcontrollers. In particular, the focus will be laid on interfacing with sensors, acquisition of data, on-board event-driven data processing with ARM-Cortex-M4 processors and BLE or other wireless transmissions. The programming will be performed in C. Today’s microcontrollers offer a lower power, efficient and cost-effective solution of tackling a nearly infinite number of task-specific applications. Ranging from IoT devices, wearable systems, sensor (mesh) devices, all the way to be integrated as submodules for the most complex system such as cars, planes, and rockets. Microcontrollers derive their advantages from the efficient use of resources and as such require very efficient and resource-saving programming. Therefore, it is mandatory to understand hardware components such as processor cores, ADC, clocks, serial communication, wireless communication, timers, interrupts, etc. The P&S includes five weeks project where the student will setup an IoT sensor node to monitor electric power transmission and distribution system.

The course will be taught in English by the ITET center for project based learning.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Project &amp; Seminars: Spiking Neural Network on Neuromorphic Processors</th>
<th>W</th>
<th>3 credits</th>
<th>3P</th>
<th>G. Indiveri</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-09L</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
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<tr>
<td></td>
<td>The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.</td>
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</table>

Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective


Compared to the "traditional" artificial neural network, the spiking neural network (SNN) can provide both latency and energy efficiency. Moreover, SNN has demonstrated in previous works a better performance in processing physiological information of small sample size, and only the output layer of the spiking neural network needs to be trained, which results in a faster training rate. This course focuses on giving the bases of spiking neural networks and neuromorphic processors. Students will learn the tools to implement SNN algorithm in both academic processors and Intel Loihi using data from Event-based Vision camera and biomedical sensors (i.e. ECG and EEG). The course will end with 4 weeks project where the students can target a specific application scenario.

The course will be taught in English.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Project &amp; Seminars: Deep Learning for Image Manipulation (DLIM)</th>
<th>W</th>
<th>3 credits</th>
<th>3P</th>
<th>L. Van Gool</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-11L</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
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</table>

Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective


With the advent of deep learning tremendous advances were achieved in numerous areas from computer vision, computer graphics, and image processing. Using these techniques, an image can be automatically manipulated in various ways with high-quality results, often fooling the human observer. Deep learning based image processing and manipulating learned image processing and manipulating based image processing technologies, including image enhancement in smartphone cameras, automated image editing, image content creation, graphics, and autonomous driving. This course focuses on the fundamentals of deep learning and image manipulation. Students will learn the tools to implement and develop deep learning solutions for a variety of image manipulation tasks. The course will end with a 4 weeks project where the students can target a specific application scenario.

The course will be taught in English.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Project &amp; Seminars: Electronic Circuits &amp; Signals Exploration Laboratory</th>
<th>W</th>
<th>2 credits</th>
<th>1P</th>
<th>H.-A. Loeliger</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-12L</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
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</table>

Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

As everyday electronic circuits have transitioned into integrated circuits, they have become increasingly difficult to examine and to tinker with. As a result, students become less exposed to basic analog electronic circuits and their fundamental operating principles. At university level, bachelor classes in analog circuits and electronics provide rigorous theoretical insights but are typically focused on linearised operating behaviour.

The goal of this lab course is to give the students the opportunity to understand how basic analog electronic circuits work, or perhaps don’t work, and provide enough practical experience for the students to feel at ease using transistors, resistors, capacitors, diodes, etc., to create working circuits.

For example, students create circuits that make physical quantities audible. Students are encouraged to utilise their own circuit ideas.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Project &amp; Seminars: Assembling and Controlling a Tuning-Fork AFM</th>
<th>W</th>
<th>3.5 credits</th>
<th>3.5P</th>
<th>T. Zambelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-13L</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
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</table>
Invented in the 1980s in Zurich and awarded with the Kavli prize in 2016, the atomic force microscope (AFM) has enabled us to visualize surfaces at the single atom level, and to measure single molecule and cell-cell interactions, deepening our understanding of material science and biology. This is achieved by controlling micromechanical piezo actuators with nanometer precision and processing noisy signals in order to achieve meaningful data.

In order to introduce you to the capabilities of modern AFMs in biomedical sensing, you will build your own setups in groups of two. You will be introduced to an AFM’s functionality, control, and signal read-out using LabView. A signal of an oscillating tuning-fork will be used as feedback for the self-built AFM. In order to better understand the working principle of a tuning fork, you will also build your own frequency sweeper and analyze it with self-built low-pass filters.

After you have implemented your own setup, you will have the chance to characterize different biomedical samples on state-of-the-art setups. This data will then be analyzed using Python.

The focus of this P&S seminar is to enable you to transfer your theoretical knowledge into practice and at the same time get to know how electrical engineering can be used in biomedical research.

The course requires active participation during the practical sessions, a 10-15 min presentation and a short written report on the acquired results. The course will be given in English.

**Domains of competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**Domain B - Method-specific Competencies**

| Analytical Competencies | assessed |
| Decision-making         | assessed |
| Media and Digital Technologies | not assessed |
| Problem-solving         | assessed |
| Project Management      | assessed |

**Domain C - Social Competencies**

| Communication          | assessed |
| Cooperation and Teamwork | assessed |
| Customer Orientation   | not assessed |
| Leadership and Responsibility | not assessed |
| Self-presentation and Social Influence | not assessed |
| Sensitivity to Diversity | not assessed |
| Negotiation            | assessed |

**Domain D - Personal Competencies**

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

**Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
</tr>
</thead>
</table>

The course can only be taken once. Repeated enrollment in a later semester is not creditable.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-15L</td>
<td>Projects &amp; Seminars: Python for Engineers - Get Productive in the Classroom, in the Lab and at Home</td>
<td>W 3 credits</td>
<td>J. Leuthold, M. Eppenberger</td>
</tr>
</tbody>
</table>

The course can only be taken once. Repeated enrollment in a later semester is not creditable.

**Objective**

More and more sustainable and renewable energy technologies are used for electricity generation to cope with climate change. These distributed resources transform the electric power grid and impose major challenges.

In this seminar, students have the opportunity to glance at cutting-edge research in the field of power systems. Possible research questions might be:

- How to integrate distributed energy generation like PV plants and wind turbines into the electricity grid?
- What challenges does the increasing share of electric vehicles and batteries impose on the power grid?
- How to cope for the uncertain generation capacity of renewables and how to forecast it?
- How does the electricity market work and how do the new sources of flexibility transform it?

Students will prepare a presentation and a report on their individual research question, which is based on an assigned paper. The main objectives are to practice literature review, scientific writing and presenting. Students will learn to independently understand specific research results – a crucial skill for academic research including semester and master projects.

The language of instruction is English. Registrations for the seminar are binding.

**Dates**

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

### Objective
Python is an interpreted high-level programming language which is becoming increasingly popular in the academic scientific community as well as in industry. The course will introduce the basics of the python programming language, and will cover some of the most useful Python modules, such as numpy, scipy and matplotlib. The classes will further cover simple GUIs, data analysis and linking with shared libraries or C code. They will further familiarize with the GIT version control system, with the linux shell and with the most common software licenses. Students are not required to have previous Python programming experience.

### Projects & Seminars: Machine Learning for Brain-Computer Interfaces

**Projects & Seminars: Machine Learning for Brain-Computer Interfaces**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**
A brain-computer interface (BCI) provides a communication and control channel based on the recognition of subject’s intention from spatiotemporal activity of the brain. A typical method to acquire neural activity signals is electroencephalography (EEG), which is often used in BCI. In order to make these data usable and get useful information out of them, signal processing techniques play a crucial role. Moreover, feature extraction and machine learning methods are applied to obtain a highly accurate BCI.

The aim of the Project and Seminars course is to give insights of signal processing and machine learning applied to brain-computer interfaces to undergraduate students, by having hands-on experience in brain signal acquisition, data processing, feature extraction, and machine learning.

**Projects & Seminars: Building a Wireless Infrared Headphone**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**
This P&S is about the design and operation of an optical infrared audio transmission system. For this purpose, we familiarize ourselves with wireless equipment and measurement equipment (oscilloscope, spectrum analyzer) and measurement methods (record frequency response, S/N ratio, nonlinear interference). The influence of modulation to suppress interference will be investigated in experiments.

Each student builds an infrared transmitter and receiver. During assembly, we gain hands-on experience with soldering conventional and SMD components. The finished circuits are tested and tuned and can be taken home afterwards.

**Projects & Seminars: Bits on Air**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**
Digital communication is a part of our everyday lives, whether we are sending e-mails, watching TV, listening to the radio, or using a cell phone. In this P&S, we will familiarize ourselves with the basics of digital communication.

On conventional PCs, the students will implement their own software modems for data transmission. These modems, just like the digital communication systems used in real life, consist of a modulator, a demodulator and an algorithm to synchronize the carrier of the incoming message. Once implemented, these modems can be used to acoustically transmit any data (such as small text files) between PCs.

We use MATLAB but previous knowledge thereof is not assumed. Rather, the goal of the project is to practice programming with MATLAB in addition to learning basics of digital communication.

**Projects & Seminars: Software Defined Radio**

Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**
Wireless transmission of information is ubiquitous today. Depending on application and frequency range, different types of modulation are used, with digital methods having largely replaced the old analog methods. Software Defined Radio (SDR) tools make it possible to dive into this world and "surf the waves" with relatively little effort. More powerful computers allow for increasingly complex signal processing in transmitters and receivers. At the same time, the signal processing algorithms can be adapted and changed very quickly and flexibly.

In this P&S we will take a closer look at how SDR works. In the first part we will work on the basics of frequencies, spectra, modulation types, and signal processing.

In the second part we will work in groups on different projects with SDR tools. Students can also bring their own ideas. At the end, the projects will be presented in the class.
The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Objectives:

The goal of the project is to create a real-world quad-rotor and use this to analyze the control and estimation techniques that are taught in the 5th semester in the Control System 1 class. The students will then design their own control function for a quad-rotor and test their ideas in simulation. The second half of the course will involve students implementing the control and estimation algorithms they designed in the real-world on our fleet of nano-quad-rotors. Once stable flight is achieved, the students will have the freedom to perform tasks with the quad-rotor. By implementing the control and estimation algorithms on a real-quadcopter, the students will gain experience with how decisions in the modeling and design stage affect real-world performance.

Important Information:

- Students must be in the 6th semester.
- The first class will be Monday, September 21 for all students.
- Classes will then occur every second week. The students will be split into two groups and the classes for each group will occur on alternating weeks. It is preferable to take the Control Systems 1 (CS1) course but not mandatory. Those students who are not taking CS1 will need to complete some extra reading to understand some aspects of this P&S.
- Due to COVID-19, the course will be offered in an online setting with classes being held over Zoom. The students will be able to take a real-world quad-rotor to their homes in order to implement the control and estimation algorithms taught in the course.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-23L</td>
<td>Projects &amp; Seminars: Phase Change Materials and Memories</td>
<td>1</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
</tr>
<tr>
<td>227-0085-24L</td>
<td>Projects &amp; Seminars: Vision and Control in RoboCup</td>
<td>3</td>
<td>Only for Electrical Engineering and Information Technology BSc.</td>
</tr>
</tbody>
</table>
Objective

Vision and Control in RoboCup is jointly offered by Prof. John Lygeros (IFA) and Prof. Luc Van Gool (CVL).

RoboCup is a tournament where teams of autonomous robots compete in soccer matches against each other. The ETH team NomadZ plays in the standard platform league with the humanoid NAO robot, where the focus lies on developing robust and efficient algorithms for vision, control and behavior. In this course, the basic challenges we encounter in RoboCup are presented and approached in practical exercises using MATLAB and Python. The topics cover visual localization, deep learning for object detection and reinforcement learning for control.

The course is offered to students of the 5th semester.

227-0085-25L  Projects & Seminars: Magnetic Resonance: From Spectrum to Image W 1 credit 1P M. Weiger Senften

The phenomenon of nuclear magnetic resonance (NMR) and its application for spectroscopy and imaging are introduced. The course starts with a general introduction to NMR, followed by measurements on a clinical MRI scanner. The NMR experiments will be developed and programmed by the students. Starting from a simple spectroscopic experiment, the basics of imaging will be acquired step-by-step. Finally, sectional images of test objects will be obtained.

In case in-classroom teaching is not allowed, the course must be cancelled. The course will be conducted only if at least 2 participants show up.

227-0085-26L  Projects & Seminars: Biosignal Acquisition and Processing for IoT Wearable Devices W 3 credits 3P

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Biosignal acquisition and processing – Wearable sensor node design and analysis for bio-impedance sensor using an Arm Cortex-M (Nordic nrf52838) Microcontroller

Wearable smart sensor electronics has the potential to revolutionize the medical field. Various body conformal flexible sensors have been used to monitor motion and physiological electrical signals such as electrocardiography (ECG), electroencephalography (EEG) and body composition analysis via body bio-impedance measurements. Smart sensor nodes not only provide accurate and continuous data in time but also automate the process of maintaining medical records, thereby lowering the workload of the health worker or clinician. This course offers an avenue for the students to understand the interdisciplinary principles that make it possible to interpret human physiology by utilizing discreet electronic components. Most importantly, participants will get a chance to do hands-on system design specific to electronically tracking a particular physiological phenomenon. In particular, the focus will be laid on programming of micro controllers, interfacing with sensors, acquisition of data and utilizing discreet analog elements for bio-signal processing. The programming will be performed in C.

The course will be taught in English and by the ITET center for project based learning.


The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective


Although the App-Industry is dominated by the giant Apps right now, it is still crucial that one knows how those Apps function and how those Apps are communicating with their hardware. This course offers the opportunity for the participants to understand the development of application using Android Studio. Most importantly, participants will get a chance to do hands-on software design specific to Android smartphone and the data acquisition from sensors, GPS, google maps and other internal devices. The main goal of the course if providing the students with the basic principle and software programming for build up every android application. The course include 4-5 weeks project were the students alone or in group will build up a working demo of a target application. The course will conclude with the presentation of the students work. Previous experience in C/Java or other languages is preferable but not mandatory. The students will program their own Android Smartphone.

The course will be taught in English by the new Project-based learning centre.


The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
ül Ulra Low Lattice FPGA – High Level Programming – Peripherals Interfacing using an Lattice FPGA

Field-programmable gate array (FPGA) is an integrated circuit designed to be configured by a customer or a designer after manufacturing, so they are also "field-programmable". The FPGA configuration is generally specified using a hardware description language (HDL), similar to that used for an application-specific integrated circuit (ASIC). However, more and more nowadays producers and open source community are providing higher level tools to program them similarly than processors. On the other side still it is important know the hardware architectures. This course will give to the students the opportunity to program FPGA in a high level way and use them to connect with external peripherals such as display, sensors, etc. In particular, the course will use the iCEBreaker FPGA boards that is specifically designed for students and engineers. They work out of the box with the latest open source FPGA development tools and next-generation open CPU architectures. The course will also iCEBreaker can be expandable through its Pmod connectors, so the students can make use of a large selection of third-party modules. The course will include a project where the students will learn how to build a full working system for the next generation of Internet of Things intelligent smart sensing.

The course will be taught in English by the new D-ITET center for Project-based learning.

227-0085-29L Projects & Seminars: Embedded Deep Learning with Huawei Atlas 200 AI Dev Kit
Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Deep Learning Intro - Python - Accelerated Embedded Computing

Deep neural networks (DNNs) have become the leading method for a wide range of data analytics tasks, after a series of major victories at the ImageNet Large Scale Visual Recognition Challenge (ILSVRC). For ILSVRC, the task was to classify images into 1000 different classes, many of which are difficult to distinguish (e.g. many classes are different breeds of dogs). All that was given were 1.2 million labelled images. Meanwhile, this recipe for success has taken over many more areas, from image-based tasks like segmenting objects in images, detecting objects, enhancing images using super-resolution and compression artifact reduction, to robotics and reinforcement learning, and a wide range of industrial applications. DNNs and their subtype convolutional neural networks (CNNs) have not been new in the 2013 when the wave of success has started, but they got this huge boost through the new availability of large-scale dataset and—at least as importantly—the availability of the necessary compute resources by using GPUs to perform the computations required during training. While GPUs were then also used to stem the high computation effort of DNNs during inference (e.g. classifying images directly using a trained DNN rather than training the DNN itself), the high demand, the need for cost efficiency, and the goal of deploying DNNs not just in data centers but pervasively in everyday devices, wearables, and low-latency industrial or interactive applications, has triggered the development of various application-specific processors which are much faster, vastly more energy efficient, and cheaper at the same time—such as the Google TPU, Graphcore, ..., and Huawei’s Ascend/Atlas platforms.

In this course, you will learn:
1) the basics of deep neural networks, how they work, and what challenges there are for inference,
2) how platforms with specialized hardware accelerators, specifically the Huawei Atlas 200, can be used for running DNN inference and getting a practical application running, and
3) work on your own project using DNNs and hardware accelerators based on your own ideas or on some of our proposals.

The course will be taught in English by the new D-ITET center for Project-Based Learning and a special guest lecturer from Huawei. Individual interactions/help can also be in (Swiss) German.

Most sessions will be around 1 hour of lecture and 2 hours of practical computer exercises. We will start an introduction and then you will have ca. 8 weeks to work on your project, which will concluded with a final presentation of your results.

227-0085-31L Projects & Seminars: Vision Goes Vegas
Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Ziel des Projektes ist es, aktuelle Methoden der Computer Vision kennen zu lernen. Die Teilnehmer des Projektes werden kleine Teams bilden und gemeinsam mit einem Assistenten die Aufgabe erarbeiten und eine Implementierung erstellen. Am Ende des Semesters sollen die Programme im öffentlichen Wettstreit gegeneinander antreten!

Als Voraussetzungen sollte Interesse an Computer Vision mitgebracht werden und die Bereitschaft, sich in einem Team von Mitstudierenden einzubringen. Kenntnisse in C++ sind notwendig.

Dieses P&S wird in englischer Sprache durchgeführt.

227-0085-32L Projects & Seminars: Magnetic Fields in our Daily Life
Only for Electrical Engineering and Information Technology BSc.

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Abstract
The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
A genome encodes a set of instructions for performing some functions within our cells. Analyzing our genomes helps, for example, to determine differences in these instructions (known as genetic variations) from human to human that may cause diseases or different traits. One benefit of knowing the genetic variations is better understanding and diagnosis of diseases and the development of efficient drugs.

Computers are widely used to perform genome analysis using dedicated algorithms and data structures. However, timely analysis of genomic data remains a daunting challenge, due to the complex algorithms and large datasets used for the analysis. Increasing the number of processing cores used for genome analysis decreases the overall analysis time, but significantly escalates the cost of building, maintaining, and cooling such a computing cluster, as well as the power/energy consumed by the cluster. This is a critical shortcoming with respect to both energy production and environmental friendliness. Cloud computing platforms can be used as an alternative to distribute the workload, but transferring the data between the clinic and the cloud poses new privacy and legal concerns.

In this course, we will cover the basics of genome analysis to understand the computational steps of the entire pipeline and find the computational bottlenecks. Students will learn about the existing efforts for accelerating one or more of these steps and will have the chance to carry out a hands-on project to improve these efforts.

Prerequisites of the course:
- No prior knowledge in bioinformatics or genome analysis is required.
- Digital Design and Computer Architecture (or equivalent course)
- A good knowledge in C programming language is required.
- Experience in at least one of the following is highly desirable: FPGA implementation and GPU programming.
- Interest in making things efficient and solving problems

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=bioinformatics

Learning Materials

3. An example of how to accelerate genomic sequence matching by two orders of magnitude with the help of FPGAs or GPUs: https://arxiv.org/abs/1912.08735
4. An example of using a different computing paradigm for accelerating read mapping step and improving its energy consumption: https://arxiv.org/pdf/1708.04329
5. An example of how to accelerate read mapping step by an order of magnitude and without using hardware acceleration: https://arxiv.org/abs/1809.07858

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**Objective**


Zum Abschluss des P&S präsentieren die einzelnen Gruppen die Erkenntnisse aus ihren Messungen fassen diese in einem kurzen Bericht zusammen.

**Projects & Seminars: Accelerating Genome Analysis with FPGAs, GPUs, and New Execution Paradigms**

3 credits

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=bioinformatics

Learning Materials

3. An example of how to accelerate genomic sequence matching by two orders of magnitude with the help of FPGAs or GPUs: https://arxiv.org/abs/1910.09020
4. An example of how to accelerate read mapping step by an order of magnitude and without using hardware acceleration: https://arxiv.org/abs/1809.07858
5. An example of using a different computing paradigm for accelerating read mapping step and improving its energy consumption: https://arxiv.org/pdf/1708.04329

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**Projects & Seminars: Exploring Future Memory Systems with RAMulator**

3 credits

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

**Abstract**

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Objective

DRAM is predominantly used to build the main memory systems of modern computing devices. Simulation-based experimental studies are key for understanding the complex interactions between DRAM and modern applications.

Ramulator is an extensible DRAM simulator providing cycle-accurate performance models for a variety of commercial DRAM standards (e.g., DDR3/4, LPDDR3/4, GDDR5, HBM) and academic proposals. Ramulator has a modular design that enables easy integration of additional DRAM standards and mechanisms. Ramulator is written in C++11 and can be easily integrated to full-system simulators such as gem5.

In this P&S, you will design new DRAM and memory controller mechanisms for improving overall system performance, energy consumption, and reliability. You will extend Ramulator with these new designs and evaluate their performance, energy consumption, and reliability using modern applications. This will be the right P&S for you if you would like to learn about the state-of-the-art memory controller and DRAM designs and their interaction with modern applications. This P&S will also enable you to hands-on simulate and understand the memory system behavior of modern workloads such as machine learning, graph analytics, genome analysis.

Prerequisites of the course:
- Digital Design and Computer Architecture (or equivalent course)
- A good knowledge in C/C++ programming language.
- Interest in making things efficient and solving problems.
- Interest in understanding software development and hardware design, and their interactions.

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=ramulator

Class: 227-0085-35L
Projects & Seminars: Enabling Secure, Reliable and Fast Memory with Hands-On FPGA Experiments

Abstract

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Objective

DRAM is predominantly used to build the main memory systems of modern computing devices. To improve the performance, reliability, and security of DRAM, it is critical to perform experimental characterization and analysis of existing cutting-edge DRAM chips.

SoftMC is an FPGA-based DRAM testing infrastructure that enables the programmer to perform all low-level DRAM operations (i.e., DDR commands) in a cycle-accurate manner. SoftMC provides a simple and intuitive high-level programming interface (in C++) that completely hides the low-level details of the FPGA from programmers. Programmers implement test routines in C++, and the test routines automatically get translated into the low-level SoftMC memory controller operations in the FPGA. SoftMC developers write low-level hardware description language code to enable new and faster studies.

In this P&S, you will have the chance to learn how DRAM is organized and operates in a low-level and gain practical experience in using SoftMC while developing SoftMC programs for new DRAM characterization studies related to performance, reliability and security. You may also improve the SoftMC infrastructure itself to enable new studies. And, who knows, you might discover new security vulnerabilities like RowHammer.

This will be the right P&S for you if you are interested in DRAM technology and would like to learn more about it as well as FPGA technology and how it can be used for practical purposes such as understanding and mitigating RowHammer attacks, generating true random numbers, reducing memory latency, fingerprinting and identifying devices, and improving reliability.

Prerequisites of the course:
- Digital Design and Computer Architecture (or equivalent course)
- Familiarity with FPGA programming
- Interest in low-level hacking and memory
- Interest in discovering why things do or do not work and solving problems

The course is conducted in English.

Course website: https://safari.ethz.ch/projects_and_seminars/doku.php?id=softmc

Class: 227-0085-36L
Projects & Seminars: Genome Sequencing on Mobile Devices

Abstract

The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

Objective

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
### Objective

Genome analysis is the foundation of many scientific and medical discoveries, and serves as a key enabler of personalized medicine. This analysis is currently limited by the inability of existing technologies to read an organism’s complete genome. Instead, a dedicated machine (called sequencer) extracts a large number of shorter random fragments of an organism’s DNA sequence, known as reads. Small, handheld sequencers such as ONT MinION and Flongle make it possible to sequence bacterial and viral genomes in the field, thus facilitating disease outbreak analyses such as COVID-19, Ebola, and Zika. However, large, capable computers are still needed to perform genome assembly, which tries to reassemble read fragments back into an entire genome sequence. This limits the benefits of mobile sequencing and may pose problems in rapid diagnosis of infectious diseases, tracking outbreaks, and near-patient testing. The problem is exacerbated in developing countries and during crises where access to the internet network, cloud services, or data centers is even more limited.

In this course, we will cover the basics of genome analysis to understand the speed-accuracy tradeoff in using computationally-lightweight heuristics versus accurate computationally-expensive algorithms. Such heuristic algorithms typically operate on a smaller dataset that can fit in the memory of today’s mobile device. Students will experimentally evaluate different heuristic algorithms and observe their effect on the end results. This evaluation will give the students the chance to carry out a hands-on project to implement one or more of these heuristic algorithms in their smartphones and help the society by enabling on-site analysis of genomic data.

### Prerequisites of the course:
- No prior knowledge in bioinformatics or genome analysis is required.
- A good knowledge in C programming language and programming is required.
- Interest in making things efficient and solving problems

The course is conducted in English.

Course website: [https://safari.ethz.ch/projects_and_seminars/doku.php?id=genome_seq_mobile](https://safari.ethz.ch/projects_and_seminars/doku.php?id=genome_seq_mobile)

### Learning Materials

3. An example of how to accelerate genomic sequence matching by two orders of magnitude with the help of FPGAs or GPUs: [https://arxiv.org/abs/1910.09029](https://arxiv.org/abs/1910.09029)
5. An example of using a different computing paradigm for accelerating read mapping step and improving its energy consumption: [https://arxiv.org/pdf/1708.04329](https://arxiv.org/pdf/1708.04329)
7. An example of a purely software method for fast genome sequence analysis: [http://www.biomedcentral.com/content/pdf/1471-227-0085-37L](http://www.biomedcentral.com/content/pdf/1471-227-0085-37L.pdf)

### Projects & Seminars: Exploring the Processing-in-Memory Paradigm for Future Computing Systems

**Only for Electrical Engineering and Information Technology BSc.**

227-0085-37L

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The course unit can only be taken once. Repeated enrollment in a later semester is not creditable.

### Abstract

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
Data movement between the memory units and the compute units of current computing systems is a major performance and energy bottleneck. From large-scale servers to mobile devices, data movement costs dominate computation costs in terms of both performance and energy consumption. For example, data movement between the main memory and the processing cores accounts for 62% of the total system energy in consumer applications. As a result, the data movement bottleneck is a huge burden that greatly limits the energy efficiency and performance of modern computing systems. This phenomenon is an undesired effect of the dichotomy between memory and the processor, which leads to the data movement bottleneck.

Many modern and important workloads such as machine learning, computational biology, graph processing, databases, video analytics, and real-time data analytics suffer greatly from the data movement bottleneck. These workloads are exemplified by irregular memory accesses, relatively low data reuse, low cache line utilization, low arithmetic intensity (i.e., ratio of operations per accessed byte), and large datasets that greatly exceed the main memory size. The computation in these workloads cannot usually compensate for the data movement costs. In order to alleviate this data movement bottleneck, we need a paradigm shift from the traditional processor-centric design, where all computation takes place in the compute units, to a more data-centric design where processing elements are placed closer to or inside where the data resides. This paradigm of computing is known as Processing-in-Memory (PIM).

This is your perfect P&S if you want to become familiar with the main PIM technologies, which represent “the next big thing” in Computer Architecture. You will work hands-on with the first real-world PIM architecture, will explore different PIM architecture designs for important workloads, and will develop tools to enable research of future PIM systems. Projects in this course span software and hardware as well as the software/hardware interface. You can potentially work on developing and optimizing new workloads for the first real world PIM hardware or explore new PIM designs in simulators, or do something else that can forward our understanding of the PIM paradigm.

Prerequisites of the course:
- Digital Design and Computer Architecture (or equivalent course).
- Familiarity with C/C++ programming.
- Interest in future computer architectures and computing paradigms.
- Interest in discovering why things do or do not work and solving problems.
- Interest in making systems efficient and usable.

The course is conducted in English.

Learning materials

1. Summary papers about recent research in PIM.
   https://people.inf.ethz.ch/omutlu/pub/ProcessingDataWhereItMakesSense_micpro19-invited.pdf

2. Ramulator-PIM: A version of Ramulator simulator for PIM.
   https://github.com/CMU-SAFARI/ramulator-pim

3. UPMEM SDK documentation: The first real-world PIM architecture.
   https://sdk.upmem.com/2020.3.0/

4. An example recent study of 3D-stacked PIM for consumer workloads.

5. An example recent study of lightweight PIM functionality on 3D-stacked memory:

6. An example recent study of a PIM accelerator for graph processing.
   https://people.inf.ethz.ch/omutlu/pub/tesseract-pim-architecture-for-graph-processing_isca15.pdf

7. An example recent study of a Processing-using-Memory system.

227-0085-38L Projects & Seminars: Controlling Biological Neuronal Networks Using Machine Learning

Does not take place this semester.

Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

The way memory and learning is achieved in the brain is an unsolved problem. Due to its relative simplicity, in-vitro neuroscience can help us discover the fundamentals of information processing in the brain. For this we can simulate a small number of biological neurons on top of an array of microelectrodes. Such an approach allows us to simulate the electrical activity of the neurons when they get stimulated.

Following this approach, we can investigate biological neural networks, that have about 5-50 neurons and a controlled network architecture. Still, their behavior remains highly unpredictable. Therefore, it is not yet clear how such networks need to be stimulated electrically in order to control their behavior. However, we can use machine learning to find a mapping between a stimulus and a desired response. More specifically, we can use reinforcement learning, since finding the right stimulation pattern is an instance of the so called multi-armed bandit problem.

This P&S consists of two parts. In the first part we will introduce you to the way neurons can be simulated. You will learn how neurons work and how they communicate. The second part will be about machine learning. We will discuss the basics of both artificial neural networks (ANN) and reinforcement learning. As homework exercises you will implement a reward function for a provided reinforcement learner, which will control your biological networks. In addition you will implement an ANN, that replaces unsatisfactorily performing stimulation patterns with new patterns, that this network evaluates to perform better.

If the current situation will allow, the developed ANNs will be tested on real neurons in our laboratory.

This P&S will be given in English. In total, the P&S takes 8 afternoons and about 50 hours of homework (ANN implementation).
Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
This beginner course to programming with Python - with a focus on applications in science and technology - is an ideal starting point for later courses. We will start with an introduction to the dev environment and tools for effective development to get you started. Then we will learn the basics of Python with exercises, and discover popular modules for data processing and visualisation that will be useful for your later studies and career. We conclude with an introduction to popular machine learning techniques and some time for you to implement your own small free-style projects.

By the end of the semester, you will:
- be familiar with your PC's command-line interface and know how to use available dev environments effectively.
- have learned the basics of Python and be able to write basic programs that do what you want (most of the time) with the help of modules.
- be able to process, visualize and analyze numerical data, e.g. lab measurements, images, etc.
- have first experience with machine learning techniques.
- maintain your first git repository and know how to collaborate with others on coding projects.

Language: English / German (if necessary)

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
What is the cache memory and how much of it does a PC need? What is the difference between DRAM and SRAM? What are bit lines, word lines, column decoders and sense amplifiers? What does precharging mean and where is it used? How does a memory cell look on silicon and how is it manufactured? You will learn these and many other things in this P&S.

Memories are important components in all modern electronic devices (e.g. computer, smartphone, TV, ...). Depending on the area of application, an engineer can look at the storage system from different perspectives. This P&S gives an overview of these different perspectives and explains the relationships between them. Since these different perspectives are not only available for memory but for all integrated circuits in general, this P&S will help you to classify further specialized knowledge in a broader context. During the exercise part of the seminar, you will work with various simulation programs. These include sophisticated programs used by engineers in research and development. So you are going to practice on professional software, and during the simulations (exercise part) and group work / lectures (seminar part) you are going to develop basic knowledge that you can later deepen during the specialized lectures.

According to the different perspectives, the P&S "Basic Memory Design" consists of three parts of roughly the same length:

- System Design: In this part you are going to learn the various current storage types from the system developer point of view. What can you achieve? How are they built into circuits in order to obtain a storage system that offers the right size and speed with acceptable energy consumption? Since there are many different types of storage, the participants will study data sheets individually and will discuss them with the P&S assistants as part of a lecture (seminar part). With a simple cache simulator you will examine the influence of the design parameters in a memory hierarchy.

- Circuit Design: In this part you are going to learn the memory as an electronic circuit. How the transistors have to be interconnected in order to be able to write, save and read out data? How should these transistors be dimensioned in order to achieve the desired speed or energy efficiency? With simulations you will experience how the engineer examines and optimizes such circuits.

- Physical Design: This part goes even deeper. Millions of transistors on a small silicon wafer form a modern memory chip. How are the memory cells produced on the chip? What does a memory cell look like? How is the memory cell optimized? With the help of modern simulation tools, you will get to know the design practices that are used during development today. You will also learn about the methods and technologies used to manufacture modern integrated circuits.
Taught competencies

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

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

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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### Projects & Seminars: Constructing a Receive Coil for Magnetic Resonance Imaging

**W** 1.5 credits 1.5P  K. P. Prüssmann

**Magnetic Resonance Imaging**

*Does not take place this semester.*

*Only for Electrical Engineering and Information Technology BSc.*

**Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.*

**Abstract**

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**

The course is about the signal detection in magnetic resonance imaging (MRI), which is a medical imaging modality. MRI is based on the principle of magnetic resonance of atomic nuclei, with corresponding signal frequencies in the order of hundreds of MHz. To receive these signals, tuned radiofrequency coils are used. The goal of this course is for participants to build such a radiofrequency coil and use it to acquire tomographic images of fruits (e.g. Orange, kiwi fruit, …) at a 7-Tesla MRI scanner. For the course, a basic understanding of electronic circuits is necessary; previous knowledge in radiofrequency engineering is advantageous but not a requirement.

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### Projects & Seminars: Clean Room Technology – Fabrication and Characterization of Photonic Materials

**W** 3 credits 3P  K. P. Prüssmann

**Projects & Seminars: Clean Room Technology – Fabrication and Characterization of Photonic Materials**

*Does not take place this semester.*

*Only for Electrical Engineering and Information Technology BSc.*

**Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.*

**Abstract**

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**

In der Nanophotonik wird die Wechselwirkung von Licht mit nanometergroßen Strukturen untersucht. So entstehen beispielsweise winzige und zugleich ultraschnelle optische Schaltkreise für eine neue Generation von Supercomputern.

Im P&S „Clean Room Technology“ erhalten die Teilnehmer einen ersten Einblick in das BRNC Hightech-Forschungslabor der ETH und IBM Zürich („Binnig and Rohrer Nanotechnology Center“). Nach einer allgemeinen Einführung in die Nanotechnologie und das Arbeiten im Reinraum, werden verschiedene nanophotonische Materialien abgeschieden. Im Anschluss werden mit Hilfe der sogenannte Ellipsometrie die optischen Eigenschaften der Materialien gemessen und anhand von Modellen am Computer analysiert. Abschluss des P&S ist eine Präsentation der Resultate und eine kurze schriftliche Zusammenfassung.

Das P&S wird für drei Gruppen à drei Teilnehmer an zehn Nachmittagen verteilt über das Semester angeboten. Wir empfehlen das P&S für Studenten im dritten Studienjahr. MATLAB Vorkenntnisse sind vorteilhaft, aber keine Voraussetzung. Das P&S findet teilweise in englischer Sprache statt.

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### Projects & Seminars: Understanding and Designing Modern Solid-State Drives (SSDs)

**W** 3 credits 3P  K. P. Prüssmann

**Projects & Seminars: Understanding and Designing Modern Solid-State Drives (SSDs)**

*Only for Electrical Engineering and Information Technology BSc.*

**Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.*

**Abstract**

The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
NAND flash memory is the de facto standard in architecting a storage device in modern computing systems. As modern computing systems process a large amount of data at an unprecedented scale, a storage device needs to meet high requirements on storage capacity and I/O performance. A NAND flash-based SSD can provide an order(s) of magnitude higher I/O performance compared to traditional hard-disk drives (HDDs), with a much lower cost-per-bit value over any other SSDs based on emerging non-volatile memory (NVM) technologies.

NAND flash memory has several unique characteristics, such as the erase-before write property (i.e., a flash cell needs to be first erased before programming it), limited lifetime (i.e., a cell can reliably store data for a certain number of program/erase cycles), and large operation units (e.g., a NAND flash chip reads/ writes data in a page (e.g., 16 KiB) granularity). To achieve high performance and large capacity of the storage system while hiding the unique characteristics of NAND flash memory, it is critical to design efficient SSD firmware, commonly called Flash-Translation Layer (FTL). An FTL is responsible for many critical management tasks, such as address translation, garbage collection, wear-leveling, and I/O scheduling, that significantly affect the performance, reliability, and lifetime of the SSD.

In this P&S, we will cover how a modern NAND flash-based SSD is organized and operates, from the basics of underlying NAND flash devices and various SSD-management tasks at the FTL-level. You will build a practical SSD simulator by refactoring MGSim, a state-of-the-art simulator for high-end SSDs, to support advanced features of modern NAND flash chips and essential SSD-management tasks. This will allow you to have the chance to obtain a comprehensive background of modern storage systems and research experience on system optimization with rigorous evaluation.

Prerequisites of the course:
- No prior knowledge in NAND flash-based storage systems is required.
- Digital Design and Computer Architecture (or equivalent course)
- Good knowledge in C/C++ programming language is required.
- Interest in system optimizations

The course is conducted in English.

**227-0085-45L Projects & Seminars: Robotic Maze Solving with a TI-RSLK Robot (RMaze)**

Does not take place this semester. Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**
Microcontroller programming (C) – Peripherals Interfacing using a MSP433 MCU – Control of a Robot in a maze

The course will focus on teaching how to build and program a Texas Instrument robotic system learning kit (TI-RSLK). It is a robot kit, which includes a 2 wheeled robot, a line sensor to determine lines on the floor as well as sensors to recognize walls. The robot is driven by a MSP432 state of the art ARM Cortex M4 processor.

This course will give the students the opportunity to learn how to program the microcontroller of this robot to navigate in a small maze. For this, the students will learn how to control the motors and, consequently the movement of the robot with the peripherals of the microcontroller. Next to the movement, also the control and readout of the attached sensors will be part of the P&S course.

Once the students are able to read sensor values and control the motors of the robot, this course will conclude with a 4-week project. Within this project the students will design their own algorithm, such that the robot can navigate autonomously within a maze. A small competition at the end of the P&S will find the fastest robot of the group.

The course will be taught in English by the new D-ITET center for Project-based learning, the programming toolchain will be installed on the student’s own laptop. Experience with microcontroller programming (C) is an advantage, however not required. A short introduction will be given during the course.

This course will be taught in English or in German if necessary.

**227-0085-46L Projects & Seminars: Embedded Systems With Drones**

Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

**Abstract**
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

**Objective**

Drones can be fun to use but understanding the hardware and software and building and programming them to be intelligent and autonomous is even better. This course gives the basis of the embedded systems having the drones as the primary target. The course will introduce embedded systems and, in particular, the microcontroller ARM Cortex-M, focusing on all the crucial blocks such as Interrupts, GPIO, ADC’s, Timers, and Serial communication protocols. Apart from the core topics, real-time and power-efficient algorithms for attitude and motor control are also discussed, making the drone efficient. Finally, exciting drone exercises are supported in the course to experiment with the development kit. The course will end with a 4-5 weeks project where the students will make the drone fly with some specific goal. It is not required any previous knowledge except C language.

The course will be taught in English and organized by the new Project-Based Learning center.

**227-0085-47L Projects & Seminars: Machine Learning on Smart Phone**

Does not take place this semester. Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.
Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Machine Learning with Smart Phone Sensors – Programming Android Phones – Neural Networks – Keras/Tensor Flow- Projects and App on smartphones

Smartphones have several sensors that can acquire much useful information, for instance where we are, what we are doing, with whom we are together, what is our constitution, what are our needs. Based on this information our 'smartphone' offers us the appropriate computational power to process them in loco without sending the sensor data to the cloud. This course focuses on giving the basics of machine learning and embedded systems. The student will learn the tools to implement a machine learning algorithm, such as Tensor Flow and others in their android phones to have an advanced smartphone. The course will end with 4 weeks project where the students can target a specific application scenario. It is not required any previous experience in machine learning. Phyton is a plus but the basis of phyton will be given in the course to be able to complete the project.

The course will be taught in English and organized by the new Project-based Learning center.

227-0085-48L Projects & Seminars: Introduction to Program Nao Robots for Robocup Competition
Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

NAO robots from Softbank are the leading humanoid robot being used in research and education worldwide. Robotics is the fastest growing and most advanced technology used in education and research. The main goal of this course is to introduce and allowing the students to learn how to program an NAO humanoid robot to make him walk, talking, watching objects understanding the human, and reacting to external input. The Nao Robots used in this course are equipped with many sensors: Tactile Sensors, Ultrasonic sensors, A Gyro, An Accelerometer, Force Sensors, Infrared sensors, 2 HD Cameras, 4 Microphones, and high accuracy digital encoders on each joint. It has two processors on board: an Intel Atom 1.6Ghz (The main computer includes SSD drive, WiFi, Bluetooth, and wired network) and an additional ARM-9 processor in its chest.

The course will introduce the software package and the full SDK and API. The students will learn how to program (mainly in C and Phyton) the robot to access the full functionality. To improve the hands-on skills of students the course will end with a 5 weeks project where the students in the group will compete in a small soccer game where the robots will play the game following and kicking a red ball. It is not requested any previous knowledge but programming skills are a plus.

The course will be taught in English and organized by the new Project-based Learning center.

227-0085-49L Projects & Seminars: Smart Patch Projects
Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective
Wearable devices, PCB Design, Firmware developing, multi-sensors, Communication.

The Smart Patch project will design autonomous, low power and mesh enabled multi-sensor wearable smart patches. They will be based on the always-on smart sensing paradigm to continuously acquire process and stream physiological data in real-time. They can be trained to autonomously detect illness symptoms or other physical conditions, such as stress. The students will work in a team to design a sub-block of the smart patch. According to the students' background, they will be associated with designing the hardware or the firmware.

Together in a team, they will learn how to structure problems and identify solutions, system analysis, and simulation, as well as presentation and documentation techniques. They will get access to D-ITET labs and state-of-the-art engineering tools (Matlab, Simulink, Firmware development IDE, PCB Design, etc.)

The projects will be done under the Smart Patches: a flagship project for D-ITET students. (pbl.ee.ethz.ch)

227-0085-51L Projects & Seminars: Hands-on Acceleration on Heterogeneous Computing Systems
Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract
The category of "Laboratory Courses, Projects, Seminars" includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.
The increasing difficulty of scaling the performance and efficiency of CPUs every year has created the need for turning computers into heterogeneous systems, i.e., systems composed of multiple types of processors that can suit better different types of workloads or parts of them. More than a decade ago, Graphics Processing Units (GPUs) became general-purpose parallel processors, in order to make their outstanding processing capabilities available to many workloads beyond graphics. GPUs have been critical key to the recent rise of Machine Learning and Artificial Intelligence, which took unrealistic training times before the use of GPUs. Field-Programmable Gate Arrays (FPGAs) are another example computing device that can deliver impressive benefits in terms of performance and energy efficiency. More specific examples are (1) a plethora of specialized accelerators (e.g., Tensor Processing Units for neural networks), and (2) near-data processing architectures (i.e., placing compute capabilities near or inside memory/storage).

Despite the great advances in the adoption of heterogeneous systems in recent years, there are still many challenges to tackle, for example:
- Heterogeneous implementations (using GPUs, FPGAs, TPUs) of modern applications from important fields such as bioinformatics, machine learning, graph processing, medical imaging, personalized medicine, robotics, virtual reality, etc.
- Scheduling techniques for heterogeneous systems with different general-purpose processors and accelerators, e.g., kernel offloading, memory scheduling, etc.
- Workload characterization and programming tools that enable easier and more efficient use of heterogeneous systems.

If you are enthusiastic about working hands-on with different software, hardware, and architecture projects for heterogeneous systems, this is your P&S. You will have the opportunity to program heterogeneous systems with different types of devices (CPUs, GPUs, FPGAs, TPUs), propose algorithmic changes to important applications to better leverage the compute power of heterogeneous systems, understand different workloads and identify the most suitable device for their execution, design optimized scheduling techniques, etc. In general, the goal will be to reach the highest performance reported for a given important application.

Prerequisites of the course:
- Digital Design and Computer Architecture (or equivalent course).
- Familiarity with C/C++ programming and strong coding skills.
- Interest in future computer architectures and computing paradigms.
- Interest in discovering why things do or do not work and solving problems.
- Interest in making systems efficient and usable.

The course is conducted in English.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0085-54L</td>
<td>Projects &amp; Seminars: Optics and Spectroscopy Lab</td>
<td>W</td>
<td>3 credits</td>
<td>4P</td>
<td>J. Leuthold</td>
</tr>
</tbody>
</table>

Objective

Projects & Seminars: Motion Sensing Technologies for Magnetic Resonance Imaging (MRI) | Only for Electrical Engineering and Information Technology BSc.

Course can only be registered for once. A repeatedly registration in a later semester is not chargeable.

Abstract

The category of “Laboratory Courses, Projects, Seminars” includes courses and laboratories in various formats designed to impart practical knowledge and skills. Moreover, these classes encourage independent experimentation and design, allow for explorative learning and teach the methodology of project work.

Objective

Current MRI scans are limited by patient motion. In clinics, radiologists are often confronted with images with severe motion artefacts in their images. They either have to make a diagnosis although the image artefacts were they could miss crucial information, or they have to send the patient back into the scanner for reacquisition. Such reacquisition might inflict additional costs in the six-figure range per scanner per year.

Further, in research, MRI images from ultra-high field systems are already limited by motion from the cardiobalistic and respiratory movement. Resulting in subpar performance if not addressed appropriately.

The key to overcoming such motion artefacts is estimating the motion and correct for it. Preferably this is done prospective in real-time or otherwise afterwards retrospective in the image reconstruction. Such methods are instrumental in brain imaging since the brain’s movement is well described by the rigid body behaviour of the skull.

To do such motion correction, one needs a motion-sensing technology to measure the movement of the human skull with high precision, accuracy and temporal resolution. All this has to be done while being integrated into an MRI machine where powerful static magnetic fields are present, kW of pulsed RF power and MVA of changing magnetic field gradients are present.

In this P&S we explore different motion sensing technologies suitable for deployment in an MRI machine. What you can expect is that we discuss the theory of multiple sensing technologies and then implement an optical, shortwave RF and NMR phase motion sensor. We will spend most of our time in the lab constructing such sensors and testing them on our robotic test bench. Finally, we would also experiment in our MRI facilities, where we would perform motion correction experiments.

Group Projects

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0091-10L</td>
<td>Group Project I</td>
<td>W</td>
<td>6 credits</td>
<td>5A</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students must work in groups in supervised projects for 150 to 180 hours minimum. The topics of the group work are open and can be technical of specific nature or more general in the context of engineering.</td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>see above</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>227-0092-10L</td>
<td>Group Project II</td>
<td>W</td>
<td>6 credits</td>
<td>5A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Abstract

Students must work in groups in supervised projects for 150 to 180 hours minimum. The topics of the group work are open and can be technical of specific nature or more general in the context of engineering.

Objective

see above

Internship in Industry

Please note the conditions for internships in industry as set forward by the "Guidelines for the "Laboratory Courses - Projects - Seminars ", see https://www.ee.ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_v5_final.pdf (German only).

<table>
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0093-10L</td>
<td>Internship in Industry</td>
<td>W</td>
<td>6 credits</td>
<td>external organisers</td>
<td></td>
</tr>
</tbody>
</table>

Number: 227-0093-10L
Title: Internship in Industry
Type: W
ECTS: 6 credits
Hours: external organisers

Abstract

The main objective of the 12-week internship is to expose bachelor's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Objective

see above

Prerequisites / notice

Please note the conditions for Internships in industry as set forward by the "Guidelines for the "Laboratory Courses - Projects - Seminars ", see https://ethz.ch/content/dam/ethz/special-interest/itet/department/Studies/Bachelor/Regulations/Richtlinien_Praktika-Projekte-Seminare_v5_final.pdf (German only).

Additional Subjects

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0651-00L</td>
<td>Applied Circuit and PCB-Design</td>
<td>W</td>
<td>2 credits</td>
<td>4G</td>
<td>A. Blanco Fontao</td>
</tr>
</tbody>
</table>

Abstract

Participants learn how to design a predefined electronic circuit and how to lay out the pertaining circuit board. CAE and CAD activities for design and simulation are carried out with the aid of Altium Designer.

Objective

The goal is to become acquainted with all those practical aspects of electronic circuit and PCB design by working through a modest but complete application example. This involves analysis of specifications, the evaluation of electronic parts, efficient testing and failure search, electromagnetic compatibility (EMC), the usage of industrial CAE/CAD tools for circuit simulation and PCB layout, generating production data for the board manufacturer, board mounting, testing and start up.

Content

- Development - from the idea to the final product
- Analysis of given circuit specifications
- Setting up the Altium Designer environment
- Structure of component libraries
- Preparing schematic symbols for CAE
- Preparing footprints for CAD
- Linking component libraries and databases
- Introduction to Concord Pro and Supply Chain Management
- Structure of schematic diagrams and circuits
- Assigning schematic functions to physical parts
- Capturing a predefined circuit
- Hints for improved testing and failure analysis
- Checking schematic data
- Simulation of mixed-signal circuits using Spice
- Introduction to PCB manufacturing
- Turning circuit schematics into a workable layout using Altium Designer
- Component placement on the PCB
- Manual and automatic interconnect routing
- Design for EMC and High-Speed
- Preparation of production data for the board manufacturer
- Documentation for manufacturing and assembly
- PCB assembly (component mounting and soldering)
- Final circuit testing and start-up.

Literature

All necessary documents will be available as electronic documents (PDF).

- The course is recommended to all students who plan to design an electronic circuit or a PCB in an upcoming term project or as part of their master thesis. Attending this course during the term before will ensure they are optimally prepared and will allow them to fully focus on their project.
- The number of participants is limited.
- For their own students and staff, the Department of Information Technology and Electrical Engineering provides electronic components and consumables free of charge. All other participants have to bear a 200 CHF fee for those items.

5th Semester: Third Year Core Courses

Can be freely combined, a list of recommendations is available under https://ee.ethz.ch/studies/bachelor/third-year/core-courses.html

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<tr>
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<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

Autumn Semester 2021
Page 698 of 2152
### Abstract
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

### Objective
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

### Content
1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.
2. The discrete Fourier transform and its use for digital filtering.
3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

### Lecture notes
Lecture Notes

### Literature
**Lecture Notes**

227-0102-00L Discrete Event Systems  
**W** 6 credits 4G R. Jacob, L. Vanbever, R. Wattenhofer

**Abstract**
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.

**Objective**
Over the last few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

**Content**
1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

**Lecture notes**
Available

[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger

D. Hochbaum

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser

227-0103-00L Control Systems  
**W** 6 credits 2V+2U F. Dörfler

**Abstract**
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

**Objective**
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.
Content

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

227-0113-00L Power Electronics W 6 credits 4G J. W. Kolar

Abstract
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Objective
Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Content
Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with single triangular carrier and individual carrier signals of the phases.

Lecture notes
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Prerequisites / notice
Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

227-0116-00L VLSI 1: HDL based design for FPGAs W 6 credits 5G F. K. Gürkaynak, L. Benini

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anean diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture Slides
Textbook and all further documents in English.

Literature

Prerequisites / notice
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

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<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites/Literature</th>
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</table>
Analog Integrated Circuits

W 6 credits 4G N. Yazdani, V. Wood

Objective
Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Content
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature

Qubits, Electrons, Photons

W 6 credits 3V+2U T. Zambelli

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Content
• (as account of those formidable years) G. Gamow, "Thirty Years that Shook Physics", 1985, Dover Publications Inc.
• (as rigorous and profound presentation of the mathematical framework) G. Dell'Antonio, "Lectures on the Mathematics of Quantum Mechanics I", 2016, Springer

Supplementary material will be uploaded in Moodle.

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in moodle!
<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Self-direction and Self-management</td>
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**227-0385-10L Biomedical Imaging**

**Abstract**
Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

**Objective**
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

**Content**
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Lecture notes**
Lecture notes and handouts

**Literature**
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Prerequisites / notice**
Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

**227-0393-10L Bioelectronics and Biosensors**

**Abstract**
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Objective**
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field
L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

5th Semester: Third Year Additional Foundation Courses
Students complete at least two of the Additional Foundation Courses available for selection. Recommendations are available under https://ee.ethz.ch/studies/bachelor/third-year/additional-foundation-courses.html

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0014-20L</td>
<td>Computational Thinking</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>R. Wattenhofer</td>
</tr>
<tr>
<td>Abstract</td>
<td>We learn: algorithmic principles, dynamic and linear programming, complexity, electronic circuits, P vs. NP, Turing machines, reductions, cryptography, zero-knowledge proofs, data organization, dictionaries, hashing, databases, SQL, machine learning, regression, clustering, deep neural networks. We will use Python as a programming language. There will be paper and programming exercises every week.</td>
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<tr>
<td>Objective</td>
<td>Computation is everywhere, but what is computation actually? In this lecture we will discuss the power and limitations of computation. Computational thinking is about understanding machine intelligence: What is computable, and how efficiently? Understanding computation lies at the heart of many exciting scientific, social and even philosophical developments. Computational thinking is more than programming a computer, it means thinking in abstractions. Consequently, computational thinking has become a fundamental skill for everyone, not just computer scientists. For example, functions which can easily be computed but not inverted are at the heart of understanding data security and privacy. Machine learning on the other hand has given us fascinating new tools to teach machines how to estimate functions. Thanks to clever heuristics, machines now appear to be capable of solving complex cognitive tasks. To give just one more example: How can we design the best electronic circuit for a given problem? In this class, we study various problems together with the fundamental theory of computation. The weekly lectures will be based on blackboard discussions and coding demos, supported by a script and coding examples. The course uses Python as a programming language. Python is popular and intuitive, a programming language that looks and feels a bit like human instructions. The lecture will feature weekly exercises, on paper and in Python.</td>
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</table>

| 227-0053-00L | High-Frequency Design Techniques          | W    | 4 credits | 2V+2U | C. Bolognesi       |
| Abstract    | Introduction to the basics of high-frequency circuit design techniques used in the realization of high-bandwidth communication systems and devices. Modern society depends on increasingly large data masses that need to be transmitted/processed as rapidly as possible: higher carrier frequencies allow wider bandwidth channels which enable higher data transmission rates. Familiarize students with the essential tools and principles exploited in high-frequency design. Introduction to circuit simulation. |
| Objective   | Introduction to wireless, radio spectrum, review of vectors and complex numbers, AC circuit analysis, matching networks, distributed circuit design, transmission lines and transmission line equations, reflection coefficients, the Smith Chart and its software, voltage standing wave ratio (VSWR), skin effect, matrix analysis, scattering parameters, electromagnetic fields and waves, antenna basics. |
| Content     | Lecture notes                             |

227-0122-00L Introduction to Electric Power Transmission: System W 4 credits 2V+2U C. Franck, G. Hug

& Technology
Introduction to theory and technology of electric power transmission systems.

Abstract
At the end of this course, the student will be able to: describe the structure of electric power systems, name the most important components and describe what they are needed for, apply models for transformers and overhead power lines, explain the technology of transformers and lines, calculate stationary power flows and other basic parameters in simple power systems.

Objective
Structure of electric power systems, transformer and power line models, analysis of and power flow calculation in basic systems.

Content
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

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

Taught
competencies
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Techniques and Technologies
Domain B - Method-specific Competencies
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Negotiation
Domain D - Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Electives
This is only a small selection. Other courses from the ETH course catalogue may be chosen. Please consult the “Richtlinien zu Projekten, Praktika, Seminare” (German only), published on our website (http://www.ee.ethz.ch/pps-richtlinien).

Economics, Law, and Management Electives
These subjects are particularly suitable for students planning to apply to the Master's Degree Program in Energy Science and Technology (MSc EST) or Management, Technology and Economics (MSc MTEC).

Number
Title
Type
ECTS
Hours
Lecturers
351-0778-00L
Discovering Management
W
3 credits
3G

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and appreciate the challenges that entrepreneurs and managers deal with.

Content
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

351-0778-01L
Discovering Management (Exercises)
W
1 credit
1U
B. Clarysse, L. P. T. Vandeweghe
Complementary exercises for the module Discovering Management.

Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

Abstract
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Content
Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management. Students have the option to either write this alone or in a group of two students.

Literature
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
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</thead>
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<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
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363-0511-00L Managerial Economics

W 4 credits 3V V. Lohmann, P. Egger, M. Köthenbürger

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective
The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature

Prerequisites / notice
The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

363-1109-00L Introduction to Microeconomics

W 3 credits 2G M. Wörter, M. Beck

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

Objective
Students acquire a deeper understanding of basic microeconomic models.

They acquire the ability to apply these models in the interpretation of real world economic contexts.

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

Content
Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

Lecture notes
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Literature

Prerequisites / notice
This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.
Students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law. They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company. They shall be familiar with the issues of corporate compliance, i.e. the system to ascertain that all legal and ethical rules are observed. They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution. They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise. They shall be able to contribute to the legal management of the company and to discuss legal issues.

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**851-0703-00L Introduction to Law**

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<th>Number of participants limited to 100</th>
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<tbody>
<tr>
<td>Students who have attended or will attend the lecture &quot;Introduction to Law for Civil Engineering and Architecture&quot; (851-0703-03L) or &quot;Introduction to Law&quot; (851-0708-00L), cannot register for this course unit.</td>
</tr>
</tbody>
</table>

**Abstract**

This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.

**Objective**

Students are able to identify basic structures of the legal system. They understand selected topics of public and private law and are able to apply the fundamentals in more advanced law classes.

**Content**

Basic concepts of law, sources of law. Private law: Contract law (particularly contract for work and services), tort law, property law. Public law: Human rights, administrative law, procurement law, procedural law. Insights into the law of the EU and into criminal law.

**Lecture notes**

Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

Further documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15142).

**851-0735-10L Business Law**

<table>
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<th>Number of participants limited to 100</th>
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<tr>
<td>Particularly suitable for students of D-ITET, D-MAVT</td>
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</table>

**Abstract**

The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.

**Objective**

The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall be familiar with the issues of corporate compliance, i.e. the system to ascertain that all legal and ethical rules are observed.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**

A comprehensive script will be made available online on the moodle platform.

**851-0738-00L Intellectual Property: Introduction**

| Particularly suitable for students of D-CHAB, D-INFK, D-ITET, D-MAVT, D-MATL, D-MTEC |

**Abstract**

The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

**Objective**

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

**851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector**

| Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT |

**Abstract**

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.
Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the protection of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Prerequisites / notice
The lecture addresses students in the fields of engineering, science and other related technical fields.

★★ Engineering Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning m</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H. -A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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</tr>
<tr>
<td>Content</td>
<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; Gaussian random variables; singular-value decomposition; kernel methods, neural networks, and more</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes will be handed out as the course progresses.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>solid basics in linear algebra and probability theory</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>227-0110-00L</td>
<td>Electromagnetic Waves: Materials, Effects, and Antennas</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>U. Koch</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course provides profound knowledge of electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.</td>
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</tr>
<tr>
<td>Content</td>
<td>The lecture covers the following topics: • Generic time-harmonic electromagnetic fields • Fundamental solutions of the wave equation • Wave propagation in various types of materials • Interaction of waves with matter • Nonlinear effects • Resonant effects • Applications like scattering, waveguiding, radiation • Radio frequency and optical antennas</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes and slides will be handed out during the lectures.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Remark: the lecture succeeds «Advanced Electromagnetic Waves» and reorientates itself to materials, effects, and applications with waves.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>227-0517-10L</td>
<td>Fundamentals of Electric Machines</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>D. Bortis</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.</td>
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<tr>
<td>Objective</td>
<td>The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.</td>
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</tr>
<tr>
<td>Content</td>
<td>- Fundamentals in magnetic circuits and electromechanical energy conversion. - Force and torque calculation. - Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine). - Complex space vector notation, rotating coordinate system (dq-transformation). - Loss components in electric machines, scaling laws of electromechanical actuators. - Mechanical and thermal modelling.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes and associated exercises including correct answers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>227-0652-00L</td>
<td>Maxwell, Einstein, and the GPS</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>T. Zambelli</td>
</tr>
<tr>
<td>Abstract</td>
<td>Maxwell’s equations are reinterpreted in the framework of Einstein’s special relativity theory using the Lagrangian formalism in order to discover the deep interconnection between the electric and magnetic field. Its daily relevance is emphasized by pinpointing how GPS atomic clocks in satellites and on the earth are affected by frequency shifts which can be explained only in terms of relativity.</td>
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</tbody>
</table>
Objective

D-ITET is the depository of the Maxwell’s equations, which are dissected from all perspectives in the courses Physics I, Electromagnetic Fields and Waves, and Advanced Electromagnetic Waves.

Only one aspect is left over: the fact that they are not invariant with respect to the classical Galilean transformation... On the contrary, Maxwell’s equations predict that the light speed is the same for every inertial frame of reference. In this new course, we will deepen how Einstein solved this clash elaborating the theory of “special relativity”. Maxwell’s equations are thus naturally derived in a breath-taking fashion from the principle of stationary action within the Lagrangian formalism.

Not only its elegance, but also the daily importance of the relativity theory will be finally highlighted explaining how the GPS can work only if the relativistic view of synchronous clocks is taken into account.

Content

• Galileo-Newton, the Ether, Michelson-Morley’s Experiment
• Lorentz Transformations
• The Lagrangian, the Principle of Stationary Action for Particles and Fields, Noether’s Theorem
• 4-Vectors in Minkowski’s Spacetime: Tensor Calculus
• Maxwell’s Equations and the Energy-Momentum Tensor
• Very First Notions of General Relativity: Einstein’s Equivalence Principle and Time Dilation
• GPS
• \( E = mc^2 \)

Lecture notes

No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

Lecture notes

!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature

• (Special Relativity) L. Susskind and A. Friedman, “Special Relativity and Classical Field Theory: The Theoretical Minimum”, 2019, Hachette Book Group USA
• (Lagrangian Formalism) L. Susskind and G. Hrabovsky, "Theoretical Minimum: What You Need to Know to Start Doing Physics", 2014, Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

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+ (on the GPS) E.D. Kaplan, C. Hegarty, “Understanding GPS/GNSS”, 2017, ARTECH HOUSE USA


Prerequisites / notice

Notions of a course on Electromagnetism like D-ITET “Electromagnetic Fields and Waves” are indispensable.

Furthermore, a solid base of Analysis I & II as well as of Linear Algebra is really helpful.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies not assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity assessed
Negotiation not assessed

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

151-0723-00L Manufacturing of Electronic Devices

W 4 credits 3G
A. Kunz, A. Guber, R.-D. Moryson, F. Reichert

Abstract

The lecture follows the value added process sequence for electronic and electronic components. It contains: Development of electric and electronic circuits, design of electronic circuits on printed circuit boards as well as in hybrid technology, integrated test technology, planning of production lines, production of highly integrated electronic on a wafer as well as recycling.

Objective

Nothing works without electronics! Typical products in mechanical engineering such as machine tools, as well as any kind of vehicle contain a significant amount of electric or electronic components of more than 60%. Thus, it is important to master the value added process sequence for electric and electronic components.

The lecture starts with a brief introduction of electronic components and the planning of integrated circuits. Next, an overview will be provided about electronic functional units assembled from these electronic components, on printed circuit boards as well as in hybrid technology. Value added process steps are shown as well as their quality check and their combination for planning a complete manufacturing line. The lecture further describes the manufacturing of integrated circuits, starting from the wafer via the structuring and bonding to the packaging. As an example, the manufacturing of micro- electromechanic and electro-optical systems and actuators is described. Due to similar processes in the electronic production, the value added process sequence for photovoltaics will be described too.

The lecture concludes with an excursion to a large manufacturing company. Here, students can see the application and realization of the manufacturing of electric and electronic devices.
Lecture notes are handed out during the individual lessons (CHF 20.-).

The lecture is partly given by experts from industry.

It is supplemented by an excursion to one of the industry partners.

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork
- Customer Orientation

Domain D - Personal Competencies

- Creative Thinking
- Critical Thinking

151-0621-00L Microsystems I: Process Technology and Integration

Abstract
Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

Objective
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (process flow).

Content
- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

Lecture notes
Handouts (available online)

Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

Prerequisites / notice
Prerequisites: Physics I and II

252-0834-00L Information Systems for Engineers

Abstract
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.
Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc

Elementary knowledge of set theory and logic

Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Materials and Mechanics in Medicine

Abstract
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering as well as a historical perspective.

Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content
Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes
course website on Moodle

Literature

Academic Press

Man-Technology-Environment Electives ("MTU")

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0227-00L</td>
<td>Basics of Air Transport (Aviation I)</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>P. Wild</td>
</tr>
</tbody>
</table>

Abstract
In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics.

Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation.

The program is taught in English and we provide 11 different experts/lecturers.

Objective
The goal is to understand and explain basics, principles and contexts of the broader air transport industry.

Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport.

Ideal foundation for Aviation II - Management of Air Transport.

Content
Weekly: 1h independent preparation; 2h lectures and 1 h training with an expert in the respective field

Concept: This course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Content: Transport as part of the overall transportation scheme; Aerodynamics; Aircraft (A/C) Designs & Structures; A/C Operations; Aviation Law; Maintenance & Manufacturers; Airport Operations & Planning; Aviation Security; ATC & Airspace; Air Freight; General Aviation; Business Jet Operations; Business models within Airline Industry; Military Aviation.

Technical visit: This course includes a guided tour at Zurich Airport and Dubendorf Airfield (baggage sorting system, apron, Tower & Radar Simulator at Skyguide Dubendorf).

Lecture notes
Preparation materials & slides are provided prior to each class

Literature
Literature will be provided by the lecturers, respectively there will be additional Information upon registration (normally available in Moodle)

Prerequisites / notice
The lecture is planned as class teaching with live-streaming and recordings.
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: assessed
- Leadership and Responsibility: not assessed
- Sensitivity to Diversity: assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed

GESS Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ITET.

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Bachelor's Project

The Bachelor's Thesis is the final part of the bachelor's program and should therefore only be taken in the semester in which the bachelor's diploma is acquired.

The minimum requirement for enrollment is the successful completion of:
- basic examination (examination blocks A+B) and
- subjects of the second year (examination blocks 1-3)

Abstract

During the Bachelor's Thesis, students will gain initial experience in the independent solution of a technical-scientific problem by applying the acquired specialist and social skills. A Bachelor's Thesis should take about half of a student's time during one semester, i.e., about 300-400 hours. The thesis includes an oral presentation and a written report, and it is graded.

Objective

see above

Prerequisites / notice

The minimum requirement for enrollment is the successful completion of:
- basic examination (examination blocks A+B) and
- subjects of the second year (examination blocks 1-3)

Supervisor must be a professor at D-ITET or associated, see a link to the lists of those at https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

How to Write Scientific Texts

Strongly recommended prerequisite for Semester Projects and Master Theses at D-ITET (MSc BME, MSc EEIT, MSc EST).

Abstract

The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be thought on two afternoons. Some exercises will be built into the lecture.

Objective

Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content

* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the "in this paper" paragraph, the scientific part, the summary, Equations, Figures).
* Topic 2: Power Point Presentations.
* Topic 3: Citation Rules and Citation Software.
* Topic 4: Guidelines for Research Integrity.
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

### Electrical Engineering and Information Technology Bachelor - Key for Type

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

### Key for Hours

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

### ECTS

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Educational Science

**General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td><strong>Human Learning (EW1)</strong></td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzentwicklung unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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</table>

| Literature  | Folien werden zur Verfügung gestellt. |
|            |                                      |

| 851-0240-22L | **Coping with Psychosocial Demands of Teaching (EW4 W2)** | W    | 2    | 3S    | U. Markwalder, S. Maurer, S. Peteranderl-Rüschoff |
|             | The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite. |
| Abstract    | In this class, students will learn concepts and skills for coping with psychosocial demands of teaching |
| Objective   | Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching. |
|             | (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks). |
|             | (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services). |

| 851-0242-05L | **Cognitively Activating Instructions in MINT Subjects** | W    | 2    | 2S    | R. Schumacher |
|             | Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport). |
| Abstract    | This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)" |
| Objective   | The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed. |
| Prerequisites | Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht. |

Learning (EW 1)“. Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

**Objective**

- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

**851-0242-11L Gender Issues In Education and STEM**

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

**Abstract**

In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM); Common perspectives, controversies and empirical evidence will be discussed.

**Objective**

- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher's work.

**Content**

Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

**Prerequisites / notice**

Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

---

**Subject Didactics and Professional Training**

*Important: You can only enroll in the courses of this category if you have not more than 12 CP left for possible additional requirements.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0857-00L</td>
<td>Subject Didactics I for D-MAVT and D-ITET</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>Q. Lohmeyer, A. Colotti</td>
</tr>
</tbody>
</table>

**Abstract**

Didactics I focuses on teaching techniques as building blocks of typical lessons. This is done on the basis of the findings of teaching and learning research and their implementation in practice. The aim is the planning and implementation of effective teaching sequences as well as their evaluation and reflection.

**Objective**

- The students can plan, conduct and critically reflect single lessons.
- They orient themselves towards the academic goals and take into account existing knowledge, the professional environment and the ambitions of the students.
- They can apply the basic teaching principles meaningfully in their subject and suitably structure the learning phases.
- They can reduce and present complex technical content such that it is in a form suitable for the students to learn.
- They have considered examples of the common conceptual errors encountered by students

**Content**

- Planning a teaching unit
- Opening a lecture
- Direct Instruction
- Blackboard writing and slide design
- Develop exercises
- Practicing teaching
- Excursion Fachhochschule

**Lecture notes**

Lecture materials are provided via Moodle.

**Prerequisites / notice**

Prerequisite: Educational science course already completed or at the same time.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0859-10L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>6</td>
<td>13P</td>
<td>A. Colotti</td>
</tr>
</tbody>
</table>

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

**Abstract**

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

**Objective**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Die Themen für die beiden Prüfungslektionen am Schluss des Praktikums erfahren die Studierenden in der Regel eine Woche vor dem Prüfungstermin. Sie erstellen eine Vorbereitung gemäß Anleitung und reichen sie bis am Vortrag um 12 Uhr den beiden Prüfungsexperten (Fachdidaktiker/-in, Departementsvertreter/-in) ein. Die gehaltenen Lektionen werden kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltenen Lektionen im Rahmen eines kurzen Kolloquiums.

Lecture notes

Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Literature

Wird von der Praktikumslehrperson bestimmt.

227-0854-00L Mentored Work Subject Didactics Electrical Engineering and Information Technology

Prerequisites: successful completion of FD I and FD II

Abstract

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective

The objective is for the students:

- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content


Typisch soll die Arbeit 3 - 4 Unterrichts-Einheiten à 45 Minuten abdecken (bei Einzelarbeit), bei Arbeit zu zweit mindestens 6 solche Einheiten.


Lecture notes

Eine kurze Anleitung zur mentorierten Arbeit in Fachdidaktik wird zur Verfügung gestellt.

Literature

K. Frey, Allgemeine Didaktik, FH-Skript bzw. Lehrbuch des Praktikumslehrers.

Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Electrical Engineering and Information Technology TC - Key for Type

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

Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Electrical Engineering and Information Technology Master

► Master Studies (Programme Regulations 2018)

►► Communication

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Communication", see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor's approval.

►►► Core Courses

These core courses are particularly recommended for the field of "Communication". You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

►►► Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>A. Wittneben</td>
</tr>
<tr>
<td>Abstract</td>
<td>Information Theory, Signal Space Analysis, Baseband Transmission, Passband Transmission, Example and Channel, Data Link Layer, MAC: Example Layer 2, Layer 3, Internet</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.</td>
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</tbody>
</table>

The application of the basic methods will be extensively explained using existing and future wireless and wired systems.

Lecture notes: Lecture Slides

Literature:


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td>Objective</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurring theme throughout the course is the stable and robust &quot;inversion&quot; of a linear filter.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
<td></td>
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<tr>
<td></td>
<td>2. The discrete Fourier transform and its use for digital filtering.</td>
<td></td>
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<tr>
<td></td>
<td>3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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</tbody>
</table>

Lecture notes: Lecture Notes

►►► Advanced Core Courses

Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0301-00L</td>
<td>Optical Communication Fundamentals</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U+1P</td>
<td>J. Leuthold</td>
</tr>
<tr>
<td>Abstract</td>
<td>The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.</td>
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<tr>
<td>Objective</td>
<td>An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.</td>
<td></td>
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</tr>
</tbody>
</table>
### Content

- **Chapter 1:** Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
- **Chapter 2:** The Transmitter: Components of a transmitter, Lasers, The spectrum of a signal, Optical modulators, Modulation formats.
- **Chapter 3:** The Optical Fiber Channel: Geometrical optics, The wave equations in a fiber, Fiber modes, Fiber propagation, Fiber losses, Nonlinear effects in a fiber.
- **Chapter 4:** The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
- **Chapter 5:** Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
- **Chapter 6:** Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
- **Chapter 7:** Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

### Lecture notes

Lecture notes are handed out.

### Literature

- Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010
- T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

### Prerequisites / notice


### 227-0417-00L Information Theory I

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>A. Lapidoth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>The fundamentals of Information Theory including Shannon's source coding and channel coding theorems</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>T.M. Cover and J. Thomas, Elements of Information Theory (second edition)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 227-0427-00L Signal Analysis, Models, and Machine Learning

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>H.-A. Loeliger</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Does not take place this semester. This course was replaced by &quot;Introduction to Estimation and Machine Learning&quot; and &quot;Advanced Signal Analysis, Modeling, and Machine Learning&quot;.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Mathematical methods in signal processing and machine learning.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Content** | I. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.  
II. Learning linear and nonlinear functions and filters: neural networks, kernel methods.  
III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events. |
| **Literature** | A. Lapidoth, "Introduction to Estimation and Machine Learning"; T. Cover and J. Thomas, Elements of Information Theory (second edition); A. Wittneben, "Advanced Signal Analysis, Modeling, and Machine Learning". |

### 227-0439-00L Wireless Access Systems

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>2V+2U</th>
<th>A. Wittneben</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Does not take place this semester.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Objective** | General learning goals of the course:  
By the end of this course, students will be able to |
- understand and illustrate the physical layer and MAC layer limits and challenges of wireless systems with emphasis on data communication and localization  
- understand and explain the functioning of the most widely used wireless systems  
- model and simulate the physical layer of state-of-the-art wireless systems  
- explain challenges and solutions of indoor localization  
- understand research challenges of future wireless networks  
Specific learning goals include:  
- Understanding the principles of OFDM and analyzing its performance on the physical layer  
- Understanding and evaluating the challenges regarding current applications of wireless networks, e.g. for the Internet-of-Things, smart grid communication, biomedical sensor communication  
- Illustrating the characteristics of the wireless channel  
- Simulation of localization and user tracking based on wireless systems  
- Explaining the basics of smart grid communications approaches (including narrowband PLC, G3-PLC) |

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The goal of the course is to explain and analyze modern and future wireless systems for data communication and localization. The course covers designs for generic applications (e.g., WiFi, Bluetooth) as well as systems optimized for specific applications (e.g., biomedical sensor networks, smart grid communications).

The course consists of two parallel tracks. The track "Technology&Systems" is structured as regular lecture. In the introduction, we discuss the challenges and potential of wireless access and study some fundamental limits of wireless communications and localization approaches.

The second part of this track is devoted to the most widely used wireless systems, WiFi/WLAN, Bluetooth, RFID, NFC. Furthermore, we study the potential of using existing wireless communication systems for indoor localization.

The third part follows with an introduction to the internet-of-things, where we focus on data communication and localization challenges and solutions in wireless networks with a massive number of nodes. Next, we study communication technologies for the smart grid, which combine wireless as well as power line communication approaches to optimize availability and efficiency.

The track is completed by a comprehensive survey of short-range magneto-inductive micro sensor networks for communication and localization - as a promising technology for biomedical sensor communication (in-body, out-of-body).

In the track "Simulate&Practice" we form student teams to simulate and analyze functional blocks of the physical layer of advanced wireless systems (based on MATLAB simulations). The track includes combination tasks in which different teams combine their functional blocks (e.g., transmitter, receiver) in order to simulate the complete physical layer of a wireless system. The focus is on data communication and localization. The tasks include modeling and simulating of single-carrier systems (as, e.g., used in Bluetooth), multi-carrier OFDM systems (e.g. used in WiFi or power line communication), and indoor localization approaches (e.g. relevant for IoT and sensor networks).

### Specialisation Courses

These specialisation courses are particularly recommended for the area of "Communication", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>R. Jacob, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.

**Objective**

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

**Content**

1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

**Lecture notes**

Available
### Literature

- [bertsekas] Data Networks
  Dimitri Bertsekas, Robert Gallager

- [borodin] Online Computation and Competitive Analysis
  Allan Borodin, Ran El-Yaniv.
  Cambridge University Press, 1998

- [boudec] Network Calculus
  J.-Y. Le Boudec, P. Thiran
  Springer, 2001

- [cassandras] Introduction to Discrete Event Systems
  Christos Cassandras, Stéphane Lafortune.

- [fial] Online Algorithms: The State of the Art
  A. Fiat and G. Woeginger

  D. Hochbaum

- [schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
  T. Schickinger, A. Steger
  Springer, Berlin, 2001

- [sipser] Introduction to the Theory of Computation
  Michael Sipser.

---

### 227-0103-00L Control Systems

#### W 6 credits 2V+2U  F. Dörfler

#### Abstract
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

#### Objective
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

#### Content

#### Literature

#### Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

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### 227-0116-00L VLSI 1: HDL based design for FPGAs

#### W 6 credits 5G  F. K. Gürkaynak, L. Benini

#### Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

#### Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

#### Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Aneou diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

#### Lecture notes
Textbook and all further documents in English.

#### Literature
Optical Communication Fundamentals

Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

Half of the oral exam will consist of a short presentation on this class project.

Handouts of presented slides. No script but an accompanying textbook is recommended.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

227-0148-00L VLSI III: Test and Fabrication of VLSI Circuits

Abstract
In this course, we will cover how modern microchips are fabricated, and we will focus on methods and tools to uncover fabrication defects, if any, in these microchips. As part of the exercises, students will get to work on an industrial 1 million dollar automated test equipment.

Objective
Learn about modern IC manufacturing methodologies, understand the problem of IC testing. Cover the basic methods, algorithms and techniques to test circuits in an efficient way. Learn about practical aspects of IC testing and apply what you learn in class using a state-of-the-art tester.

Content
In this course we will deal with modern integrated circuit (IC) manufacturing technology and cover topics such as:
- Today’s nanometer CMOS fabrication processes (HKMG).
- Optical and post optical Photolithography.
- Potential alternatives to CMOS technology and MOSFET devices.
- Evolution paths for design methodology.
- Industrial roadmaps for the future evolution of semiconductor technology (ITRS).

If you want to earn money by selling ICs, you will have to deliver a product that will function properly with a very large probability. The main emphasis of the lecture will be discussing how this can be achieved. We will discuss fault models and practical techniques to improve testability of VLSI circuits. At the IIS we have a state-of-the-art automated test equipment (Advantest SoC V93000) that we will make available for in class exercises and projects. At the end of the lecture you will be able to design state-of-the-art digital integrated circuits such as to make them testable and to use automatic test equipment (ATE) to carry out the actual testing.

During the first weeks of the course there will be weekly practical exercises where you will work in groups of two. For the last 5 weeks of the class students will be able to choose a class project that can be:
- The test of their own chip developed during a previous semester thesis
- Developing new setups and measurement methods in C++ on the tester
- Helping to debug problems encountered in previous microchips by IIS.

Half of the oral exam will consist of a short presentation on this class project.


Although this is the third part in a series of lectures on VLSI design, you can follow this course even if you have not visited VLSI I and VLSI II lectures. An interest in integrated circuit design, and basic digital circuit knowledge is required though.

Course website: https://iis-students.ee.ethz.ch/lectures/vlsi-iii/

227-0166-00L Analog Integrated Circuits

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.


Handouts of presented slides. No script but an accompanying textbook is recommended.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

227-0301-00L Optical Communication Fundamentals

Abstract
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Content
* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
* Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes
Lecture notes are handed out.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0377-10L</td>
<td>Physics of Failure and Reliability of Electronic Devices and Systems</td>
<td>3</td>
<td>W</td>
<td>I. Shorubalko, M. Held</td>
</tr>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>4</td>
<td>W</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>6</td>
<td>W</td>
<td>L. Van Gool, E. Konukoglu, F. Yu</td>
</tr>
<tr>
<td>227-0468-00L</td>
<td>Analog Signal Processing and Filtering</td>
<td>6</td>
<td>W</td>
<td>H. Schmid</td>
</tr>
</tbody>
</table>

**Abstract**
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

**Objective**
Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

**Content**
Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

**Lecture notes**
Comprehensive copy of transparencies

**Literature**

**Course code and title**

- **227-0377-10L** Physics of Failure and Reliability of Electronic Devices and Systems
- **227-0423-00L** Neural Network Theory
- **227-0447-00L** Image Analysis and Computer Vision
- **227-0468-00L** Analog Signal Processing and Filtering

**Prerequisites**

**Content**

1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

**Prerequisites**
- Detailed lecture notes are available on the course web page [https://www.mins.ee.ethz.ch/teaching/nt](https://www.mins.ee.ethz.ch/teaching/nt)

**Prerequisites**
- This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

**Prerequisites**
- Course material Script, computer demonstrations, exercises and problem solutions

**Objective**
- After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

**Abstract**
- The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

**Objective**
- Suitable for Master Students as well as Doctoral Students.
- The course language is English.
### Content
At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits“ complements this lecture very well in that respect.

### Lecture notes
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c/order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

### Prerequisites / notice
Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria...) and of the main properties of linear systems is necessary.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Subject-specific Competencies</th>
<th>Taught</th>
<th>G</th>
<th>K. Heutsch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A</td>
<td>Concepts and Theories</td>
<td>assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain B</td>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain B</td>
<td>Decision-making</td>
<td>assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain B</td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain B</td>
<td>Problem-solving</td>
<td>assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Communication</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Customer Orientation</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain C</td>
<td>Negotiation</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Creative Thinking</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Critical Thinking</td>
<td>assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
<tr>
<td>Domain D</td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
<td>6</td>
<td>4G</td>
</tr>
</tbody>
</table>

### 227-0477-00L
**Acoustics I**

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound propagation and room acoustics of large and small enclosures.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Understanding of the basic acoustical concepts and methods. Ability to understand the technical and scientific literature. Confidence in the use of measuring instruments.</td>
</tr>
<tr>
<td>Content</td>
<td>Fundamentals of acoustics, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, architectural acoustics, noise and noise control, calculation of sound fields.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>yes</td>
</tr>
<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies: Concepts and Theories, assessed</td>
</tr>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies: Analytical Competencies, assessed, Problem-solving, assessed</td>
</tr>
<tr>
<td></td>
<td>Domain C - Social Competencies: Communication, not assessed, Self-presentation and Social Influence, not assessed</td>
</tr>
<tr>
<td></td>
<td>Domain D - Personal Competencies: Adaptability and Flexibility, not assessed, Creative Thinking, Critical Thinking, assessed, Self-awareness and Self-reflection, Self-direction and Self-management, not assessed</td>
</tr>
</tbody>
</table>

### 227-0652-00L
**Maxwell, Einstein, and the GPS**

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Maxwell's equations are reinterpreted in the framework of Einstein's special relativity theory using the Lagrangian formalism in order to discover the deep interconnection between the electric and magnetic field. Its daily relevance is emphasized by pinpointing how GPS atomic clocks in satellites and on the earth are affected by frequency shifts which can be explained only in terms of relativity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>D-ITET is the depository of the Maxwell's equations, which are dissected from all perspectives in the courses Physics I, Electromagnetic Fields and Waves, and Advanced Electromagnetic Waves. Only one aspect is left over: the fact that they are not invariant with respect to the classical Galilean transformation… On the contrary, Maxwell’s equations predict that the light speed is the same for every inertial frame of reference. In this new course, we will deepen how Einstein solved this clash elaborating the theory of “special relativity”. Maxwell’s equations are thus naturally derived in a breath-taking fashion from the principle of stationary action within the Lagrangian formalism.</td>
</tr>
<tr>
<td></td>
<td>Not only its elegance, but also the daily importance of the relativity theory will be finally highlighted explaining how the GPS can work only if the relativistic view of synchronous clocks is taken into account.</td>
</tr>
</tbody>
</table>

Content

- Galileo-Newton, the Ether, Michelson-Morley's Experiment
- Lorentz Transformations
- The Lagrangian, the Principle of Stationary Action for Particles and Fields, Noether's Theorem
- 4-Vectors in Minkowski's Spacetime: Tensor Calculus
- Maxwell's Equations and the Energy-Momentum Tensor
- GPS
- \( E = mc^2 \)

Lecture notes

No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature

- (Special Relativity) L. Susskind and A. Friedman, "Special Relativity and Classical Field Theory: The Theoretical Minimum", 2019, Hachette Book Group USA

Supplementary material will be uploaded in Moodle.

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+ (on the GPS) E.D. Kaplan, C. Hegarty, "Understanding GPS/GNSS", 2017, ARTECH HOUSE USA

Prerequisites / notice

Notions of a course on Electromagnetism like D-ITET "Electromagnetic Fields and Waves" are indispensable. Furthermore, a solid base of Analysis I & II as well as of Linear Algebra is really helpful.

IMPORTANT: Wed 22.9, 29.9, 3.11, 10.11, 8.12, and 22.12 are lectures (NOT exercises!). Please, look at the details in Moodle!

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems
Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

<table>
<thead>
<tr>
<th>263-4640-00L</th>
<th>Network Security</th>
<th>W</th>
<th>8 credits</th>
<th>2V+2U+3A</th>
<th>A. Perrig, S. Frei, M. Legner, K. Paterson</th>
</tr>
</thead>
</table>

Abstract

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. Analysis and inference topics such as traffic monitoring and network forensics; and

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Taught competencies

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

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

Domain C - Social Competencies
- Communication not assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility not assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management assessed

<table>
<thead>
<tr>
<th>401-3055-64L</th>
<th>Algebraic Methods in Combinatorics</th>
<th>W</th>
<th>6 credits</th>
<th>2V+1U</th>
<th>B. Sudakov</th>
</tr>
</thead>
</table>

Abstract

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure $A$ one maps its elements to vectors in a linear space, and shows that the set $A$ is mapped to linearly independent vectors. It then follows that the cardinality of $A$ is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

The individual study plan is subject to the tutor’s approval.

### Core Courses

These core courses are particularly recommended for the field of "Computers and Networks". You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

### Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>R. Jacob, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

Abstract

Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.
Objective

Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content

1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes

Available

Literature

[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger
D. Hochbaum

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser.

227-0121-00L Communication Systems

W 6 credits 4G A. Wittneben

Abstract

Information Theory, Signal Space Analysis, Baseband Transmission, Passband Transmission, Example and Channel, Data Link Layer, MAC, Example Layer 2, Layer 3, Internet

Objective

Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems

Content

Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.

The application of the basic methods will be extensively explained using existing and future wireless and wired systems.

Lecture notes

Lecture Slides

Literature


227-0124-00L Embedded Systems

W 6 credits 4G L. Thiele, M. Magno

Abstract

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.

Understanding specific requirements and problems arising in embedded system applications.

Using the formal models and methods in embedded system design in practical applications using the programming language C, the operating system FreeRTOS, a commercial embedded system platform and the associated design environment.

Understanding architectures and components, their hardware-software interfaces, the memory architecture, communication between components, embedded operating systems, real-time scheduling theory, shared resources, low-power and low-energy design as well as hardware architecture synthesis.

**Content**
An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.

The focus of this lecture is on the design of embedded systems using formal models and methods as well as computer-based synthesis methods. Besides, the lecture is complemented by laboratory sessions where students learn to program in C, to base their design on the embedded operating systems FreeRTOS, to use a commercial embedded system platform including sensors, and to edit/debug via an integrated development environment.

Specifically the following topics will be covered in the course: Embedded system architectures and components, hardware-software interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.

More information is available at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

**Lecture notes**
The following information will be available: Lecture material, publications, exercise sheets and laboratory documentation at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

**Literature**


Prerequisites / notice
Prerequisites: Basic knowledge in computer architectures and programming.

---

#### Advanced Core Courses

**Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-2210-00L</td>
<td>Computer Architecture</td>
<td>W</td>
<td>8 credits</td>
<td>6G+1A</td>
<td>O. Mutlu</td>
</tr>
<tr>
<td>Abstract</td>
<td>Computer architecture is the science &amp; art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.</td>
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<tr>
<td>Objective</td>
<td>We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc.</td>
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<tr>
<td>Content</td>
<td>The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).</td>
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<tr>
<td>Lecture notes</td>
<td>All the materials (including lecture slides) will be provided on the course website: <a href="https://safari.ethz.ch/architecture/">https://safari.ethz.ch/architecture/</a></td>
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<tr>
<td>Literature</td>
<td>The video recordings of the lectures are expected to be made available after lectures.</td>
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</table>

| 227-0575-00L | Advanced Topics in Communication Networks | W | 6 credits | 2V+2U | L. Vanbever |
| Abstract     | This course covers advanced topics and technologies in computer networks, both theoretically and practically. It is offered each Fall semester, with rotating topics. Repetition for credit is possible with consent of the instructor. In the Fall 2021, the course will cover advanced topics in Internet routing and forwarding. |
| Objective    | The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet routing and forwarding technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments, and even implement some of them on their own during labs and a final group project. |
| Content      | The course will cover advanced topics in Internet routing and forwarding such as: |
|              | - Tunneling |
|              | - Hierarchical routing |
|              | - Traffic Engineering and Load Balancing |
|              | - Virtual Private Networks |
|              | - Quality of Service/Queueing/Scheduling |
|              | - Fast Convergence |
|              | - Network virtualization |
|              | - Network programmability (OpenFlow, P4) |
|              | - Network measurements |
|              | The course will be divided in two main blocks. The first block (~8 weeks) will interleave classical lectures with practical exercises and labs. The second block (~6 weeks) will consist of a practical project which will be performed in small groups (~3 students). During the second block, lecture slots will be replaced by feedback sessions where students will be able to ask questions and get feedback about their project. |
|              | The last week of the semester will be dedicated to student presentations and demonstrations. |
| Lecture notes| Lecture notes and material will be made available before each course on the course website. |
| Literature   | Relevant references will be made available through the course website. |
| Prerequisites / notice | Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding. |
By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.
### Specialisation Courses

These specialisation courses are particularly recommended for the area of ‘Computers and Networks’, but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td>Objective</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust “inversion” of a linear filter.</td>
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<tr>
<td>Content</td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
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<td>2. The discrete Fourier transform and its use for digital filtering.</td>
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<td></td>
<td>3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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<td>Lecture notes</td>
<td>Lecture Notes</td>
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<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
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<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<td>Objective</td>
<td>Design of control systems for single input - single output and multivariable systems.</td>
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<td>Prerequisites /</td>
<td>Prerequisites: Signal and Systems Theory II.</td>
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<tr>
<td>notice</td>
<td>MATLAB is used for system analysis and simulation.</td>
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<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL based design for FPGAs</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>F. K. Gürkaynak, L. Benini</td>
</tr>
<tr>
<td>Abstract</td>
<td>This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.</td>
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<tr>
<td>Objective</td>
<td>Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.</td>
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</table>
Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
  - Register Transfer Level (RTL) synthesis and its limitations.
  - Building blocks of digital VLSI circuits.
  - Functional verification techniques and their limitations.
  - Modular and largely reusable testbenches.
  - Assertion-based verification.
  - Synchronous versus asynchronous circuits.
  - The case for synchronous circuits.
  - Periodic events and the Anceau diagram.
  - Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature

Prerequisites / notice
Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>ECTS</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0377-10L</td>
<td>Physics of Failure and Reliability of Electronic Devices and Systems</td>
<td>W 3 credits</td>
<td>2V</td>
<td>I. Shorubalko, M. Held</td>
</tr>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>W 6 credits</td>
<td>3V+1U</td>
<td>L. Van Gool, E. Konukoglu, F. Yu</td>
</tr>
<tr>
<td>227-0555-00L</td>
<td>Distributed Systems</td>
<td>W 4 credits</td>
<td>3G+1A</td>
<td>R. Wattenhofer</td>
</tr>
</tbody>
</table>

Abstract
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

Objective
Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

Content
Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

Lecture notes
Comprehensive copy of transparencies

Literature

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

We discuss the following concepts related to fault-tolerant distributed systems: client-server, serialization, two-phase protocols, three-phase protocols, Paxos, two generals problem, crash failures, impossibility of consensus, Byzantine failures, agreement, termination, validity, Byzantine agreement, King algorithm, asynchronous Byzantine agreement, authentication, signatures, reliable and atomic broadcast, eventual consistency, blockchain, cryptocurrencies such as Bitcoin and Ethereum, proof-of-work, proof-of-stake, smart contracts, quantum systems, fault-tolerant protocols such as pChain or pbft, distributed storage, distributed hash tables, physical and logical clocks, causality, selflessness, game theoretic models, mechanism design.

A script is available on the web page. The script is self-contained, but links to additional material are available on the web page.

This lecture takes place in roughly the second half of the semester, as the lecture is the second part of the lecture "Computer Systems" (252-0217-00). Students may attend at most one of the two lectures, NOT both.

### 151-0593-00L Embedded Control Systems

**Abstract**

This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

**Objective**

Familiarize students with main architectural principles and concepts of embedded control systems.

An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital IO and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

**Prerequisites / notice**

Lecture notes, lab instructions, supplemental material

Prerequisite courses are Control Systems I and Informatics I.

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch)

After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website [http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html](http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html)

### 252-1411-00L Security of Wireless Networks

**Abstract**

Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.

After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless networks and systems: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

**Content**


### 401-3055-64L Algebraic Methods in Combinatorics

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Objective**

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem, Applications for such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

**Lecture notes**

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Prerequisites / notice**

Lectures will be on the blackboard only, but there will be a set of typset lecture notes which follow the class closely.

Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Electronics and Photonics

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Electronics and Photonics", see [https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html](https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html).

The individual study plan is subject to the tutor's approval.

### Core Courses
These core courses are particularly recommended for the field of "Electronics and Photonics". You may choose core courses from other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

#### Foundation Core Courses

**Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0110-00L</td>
<td>Electromagnetic Waves: Materials, Effects, and Antennas</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>U. Koch</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This course provides profound knowledge of electromagnetic waves. Various types of materials, nonlinear and resonant effects, and antenna applications are discussed.</td>
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<td><strong>Objective</strong></td>
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<td>You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td>The lecture covers the following topics:</td>
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<td>• Generic time-harmonic electromagnetic fields</td>
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<td>• Fundamental solutions of the wave equation</td>
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<td></td>
<td>• Wave propagation in various types of materials</td>
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<td>• Interaction of waves with matter</td>
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<td></td>
<td>• Nonlinear effects</td>
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<td>• Resonant effects</td>
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<td></td>
<td>• Applications like scattering, waveguiding, radiation</td>
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<td></td>
<td>• Radio frequency and optical antennas</td>
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<td><strong>Lecture notes</strong></td>
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<td>Lecture notes and slides will be handed out during the lectures.</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td>Remark: the lecture succeeds «Advanced Electromagnetic Waves» and reorientates itself to materials, effects, and applications with waves.</td>
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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL based design for FPGAs</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>F. K. Gürkaynak, L. Benini</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASICs or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:</td>
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<td>• Overview on design methodologies and fabrication depths.</td>
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<td>• Levels of abstraction for circuit modeling.</td>
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<td>• Organization and configuration of commercial field-programmable components.</td>
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<td></td>
<td>• FPGA design flows.</td>
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<td>• Dedicated and general purpose architectures compared.</td>
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<td>• How to obtain an architecture for a given processing algorithm.</td>
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<td>• Meeting throughput, area, and power goals by way of architectural transformations.</td>
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<td>• Hardware Description Languages (HDL) and the underlying concepts.</td>
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<td></td>
<td>• SystemVerilog</td>
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<td>• Register Transfer Level (RTL) synthesis and its limitations.</td>
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<td>• Building blocks of digital VLSI circuits.</td>
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<td>• Functional verification techniques and their limitations.</td>
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<td></td>
<td>• Modular and largely reusable testbenches.</td>
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<td>• Assertion-based verification.</td>
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<td>• Synchronous versus asynchronous circuits.</td>
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<td>• The case for synchronous circuits.</td>
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<td>• Periodic events and the Anceau diagram.</td>
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<td></td>
<td>• Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Textbook and all further documents in English.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td>Prerequisites: Basics of digital circuits.</td>
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<td><strong>Examination</strong></td>
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<td>In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.</td>
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<td><strong>Further details:</strong></td>
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<td><a href="https://iis-students.ee.ethz.ch/lectures/vlsi-i/">https://iis-students.ee.ethz.ch/lectures/vlsi-i/</a></td>
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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0145-00L</td>
<td>Solid State Electronics and Optics</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>N. Yazdani, V. Wood</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>&quot;Solid State Electronics&quot; is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magnetoresistance, and optical properties of solids.</td>
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<td><strong>Objective</strong></td>
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<td>Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td><strong>Recommended background:</strong></td>
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<td>Undergraduate physics, mathematics, semiconductor devices</td>
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<tbody>
<tr>
<td>227-0166-00L</td>
<td>Analog Integrated Circuits</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>T. Jang</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.</td>
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### Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

### Content
- Review of bipolar and MOS devices and their small-signal equivalent circuit models: Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.
- Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The lecture and exercise session aim to reinforce the lecture material by well guided step-by-step design tasks. The task simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

### Literature
- M. Gustavsson et. al., CMOS Data Converters for Communications, Springer, 2010
- Vishwani D. Agrawal, Springer, 2004. This book is available online within ETH through available for in class exercises and projects. At the end of the lecture you will be able to design state-of-the-art digital integrated circuits

### Prerequisites / notice
It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.

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## Advanced Core Courses

**Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.**

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0146-00L</td>
<td>Analog-to-Digital Converters</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>L. Benini</td>
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</tbody>
</table>

### Abstract
This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.

### Objective
Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. The student will learn to understand the basic principles behind data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained with their principle of operation accompanied with the appropriate mathematical calculations, including the effects of non-idealities in some cases. After successful completion of the course the student should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.

### Content
- Introduction: information representation and communication; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.
- Dual-slope & successive approximation register (SAR) converters; dual slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array.
- Algorithmic & pipelined A/D converters: algorithmic conversion principle; sample & hold stage; pipeline converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction.
- Performance metrics and non-linearity: ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.
- Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.
- Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.
- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.

### Lecture notes
Slides are available online under https://lis-students.ee.ethz.ch/lectures/analog-to-digital-converters/.

### Literature
- M. Gustavsson et. al., CMOS Data Converters for Communications, Springer, 2010

### Prerequisites / notice
It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.

---

## VLSI III: Test and Fabrication of VLSI Circuits

**Does not take place this semester.**

### Abstract
In this course, we will cover how modern microchips are fabricated, and we will focus on methods and tools to uncover fabrication defects, if any, in these microchips. As part of the exercises, students will get to work on an industrial 1 million dollar automated test equipment.

### Objective
Learn about modern IC manufacturing methodologies, understand the problem of IC testing. Cover the basic methods, algorithms and techniques to test circuits in an efficient way. Learn about practical aspects of IC testing and apply what you learn in class using a state-of-the-art tester.

### Content
- Today's nanometer CMOS fabrication processes (HKMG).
- Optical and post optical Photolithography.
- Potential alternatives to CMOS technology and MOSFET devices.
- Evolución paths for design methodology.
- Industrial roadmaps for the future evolution of semiconductor technology (ITRS).

If you want to earn money by selling ICs, you will have to deliver a product that will function properly with a very large probability. The main emphasis of the lecture will be discussing how this can be achieved. We will discuss fault models and practical techniques to improve testability of VLSI circuits. At the IIS we have a state-of-the-art automated test equipment (Advantest SoC V93000) that we will make available for in class exercises and projects. At the end of the lecture you will be able to design state-of-the-art digital integrated circuits such as to make them testable and to use automatic test equipment (ATE) to carry out the actual testing.

During the first weeks of the course there will be weekly practical exercises where you will work in groups of two. For the last 5 weeks of the class students will be able to choose a class project that can be:
- The test of their own chip developed during a previous semester thesis
- Developing new setups and measurement methods in C++ on the tester
- Helping to debug problems encountered in previous microchips by IIS.

Half of the oral exam will consist of a short presentation on this class project.

### Lecture notes
Although this is the third part in a series of lectures on VLSI design, you can follow this course even if you have not visited VLSI I and VLSI II lectures. An interest in integrated circuit design, and basic digital circuit knowledge is required though.

Course website: https://iis-students.ee.ethz.ch/lectures/vlsi-iii/

227-0301-00L
Optical Communication Fundamentals

Abstract
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Content

* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.

* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.

* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.

Content

* Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes are handed out.

Literature
Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010

Prerequisites / notice

227-0655-00L
Nonlinear Optics

Abstract
Nonlinear Optics deals with the interaction of light with material, the response of material to light and the mathematical framework to describe the phenomena. As an example we will cover fundamental phenomena such as the refractive index, the electro-optic effect, second harmonic generation, four-wave mixing or soliton propagation and others.

Objective
The important nonlinear optical phenomena are understood and can be classified. The effects can be described mathematical by means of the susceptibility.

Content
Chapter 1: The Wave Equations in Nonlinear Optics
Chapter 2: Nonlinear Effects - An Overview
Chapter 3: The Nonlinear Optical Susceptibility
Chapter 4: Second Harmonic Generation
Chapter 5: The Electro-Optic Effect and the Electro-Optic Modulator
Chapter 6: Acousto-Optic Effect
Chapter 7: Nonlinear Effects of Third Order
Chapter 8: Nonlinear Effects in Media with Gain

Literature
Lecture notes are distributed. For students enrolled in the course, additional information, lecture notes and exercises can be found on moodle (https://moodle-app2.let.ethz.ch/).

Prerequisites / notice
Fundamentals of Electromagnetic Fields (Maxwell Equations) & Bachelor Lectures on Physics.

227-0663-00L
Nano-Optics

Abstract
Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.

Objective
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Content
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

Prerequisites / notice
- Electromagnetic fields and waves (or equivalent)
- Physics I-II

227-0147-10L
VLSI 3: Full-Custom Digital Circuit Design

Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals are to learn how to design digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

Objective
At the end of this course you will
- understand how the main building blocks of state-of-the-art digital integrated circuits are designed
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between speed, area, and power consumption
Content
The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:
- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverter
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning
These exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Literature
N. H. E. Weste and D. M Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

Prerequisites / notice
VLSI3 can be taken in parallel with “VLSI1: HDL based design for FPGAs” and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

### Specialisation Courses

These specialisation courses are particularly recommended for the area of “Electronics and Photonics”, but you are free to choose courses from any other field in agreement with your tutor.

**A minimum of 40 credits must be obtained from specialisation courses during the Master’s Programme.**

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<tbody>
<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>A. Wittneben</td>
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<tr>
<td>Abstract</td>
<td>Information Theory, Signal Space Analysis, Baseband Transmission, Passband Transmission, Example and Channel, Data Link Layer, MAC, Example Layer 2, Layer 3, Internet</td>
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<tr>
<td>Objective</td>
<td>Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems</td>
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<tr>
<td>Content</td>
<td>Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.</td>
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Lecture notes
Lecture Slides

Literature

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0155-00L</td>
<td>Machine Learning on Microcontrollers</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>M. Magno, L. Benini</td>
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<tr>
<td>Registration</td>
<td>Registration in this class requires the permission of the instructors. Class size will be limited to 25. Preference is given to students in the MSc EEIT.</td>
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<tr>
<td>Abstract</td>
<td>Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V)</td>
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<tr>
<td>Objective</td>
<td>Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.</td>
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<tr>
<td>Content</td>
<td>The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:</td>
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<tr>
<td>License notes</td>
<td>Script and exercise sheets. Books will be suggested during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable</td>
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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0157-00L</td>
<td>Semiconductor Devices: Physical Bases and Simulation</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>A. Schenk, C. I. Roman</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.</td>
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At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of GaN filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements this lecture very well in that respect.

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signallowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

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Introduction to solar radiation, physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency wafer-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture).

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain B - Method-specific Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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

Domain D - Personal Competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Prerequisites / notice
Undergraduate physics, mathematics, semiconductor devices

Prerequisites / notice
Lecture reprints (in english).

Prerequisites / notice
Prerequisites: Basic knowledge of semiconductor properties.

This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modeling of power semiconductors, as well on the related built-in reliability strategies.
The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for experimental thermal, thermal, and electro-thermal simulation of power semiconductors by Technology Computer Aided Design (TCAD) and compact modeling. Finally, procedures are methods to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

During the laboratory activities, selections of the experimental techniques presented in the lecture are demonstrated on the base of realistic examples. Furthermore, schematic power devices will be simulated by the students with advanced TCAD tools and circuit simulators.

Objective  
This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for experimental thermal, thermal, and electro-thermal simulation of power semiconductors by Technology Computer Aided Design (TCAD) and compact modeling. Finally, procedures are methods to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

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### Taught competencies

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<tr>
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<tr>
<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
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### Electromagnetic Precision Measurements and Opto-Mechanics

**227-0653-00L**

**Objective**
The goal of this course is to understand the fundamental limitations of measurement systems relying on electromagnetic fields.

**Content**
The course starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insights at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics.

**Prerequisites**
1. Electrodynamics
2. Physics 1.2
3. Introduction to quantum mechanics

**Integrated Systems Seminar**

**227-0659-00L**

**Abstract**
The seminar aims at instructing graduate and PhD students in the basics of presentation techniques, i.e. "how to give a professional talk". Attendees have the possibility to become acquainted with a current topic by a literature study, and to present the results thereof in a 20 minutes talk in English. The participation at the seminar gives also an overview on current problems in modern nano- and opto-electronics.

**Objective**
The seminar topics are simulation of nanoelectronic processes and devices, and the optical as well as electronical simulation of optoelectronic devices as lasers, photodiodes, etc.

**Content**
The students learn how to find the right literature for a certain topic quickly, as well as how to prepare a talk for a scientific conference, i.e. presentation techniques.

**Battery Integration Engineering**

**227-0665-00L**

**Abstract**
Batteries enable sustainable mobility, renewable power integration, various power grid services, and residential energy storage. Linked with low cost PV, Li-ion batteries are positioned to shift the 19th-century centralized power grid into a 21st-century distributed one. As with battery integration, this course combines understanding of electrochemistry, heat & mass transfer, device engineering.

**Objective**
The learning objectives are:
- Apply critical thinking on advancements in battery integration engineering. Assessment reflects this objective and is based on review of a scientific paper, with mark weighting of 10 / 25 / 65 for a proposal / oral presentation / final report, respectively.
- Design battery system concepts for various applications in the modern power system and sustainable mobility, with a deep focus on replacing diesel buses with electric buses combined with charging infrastructure.
- Critically assess progresses in battery integration engineering: from material science of novel battery technologies to battery system design.
- Apply "lessons learned" from the history of batteries to assess progress in battery technology.
- Apply experimental and physical concepts to develop battery models in order to predict lifetime.
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Prerequisites / notice**
- Limited to 30 Students. Priority given to Electrical and Mechanical Engineering students.

Mandatory - background knowledge in batteries & electrochemistry acquired in one of the following courses:
- 227-0664-00L Technology and Policy of Electrical Energy Storage
- 529-0440-00L Physical Electrochemistry and Electrocatalysis
- 529-0191-01L Renewable Energy Technologies II, Energy Storage and Conversion
- 529-0659-00L Electrochemistry

Exception given for PhD students

**227-1033-00L Neuromorphic Engineering I**

*Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.*

**Information for UZH students:**
- Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.
- Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

**Abstract**
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

**Objective**
Understanding of the characteristics of neuromorphic circuit elements.

**Content**
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on the physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina, silicon cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

**Literature**
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

**Prerequisites / notice**
Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

**227-2037-00L Physical Modelling and Simulation**

*This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.*

**Abstract**
This module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. The course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations such as finite element analysis, finite element analysis for MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or choose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

**151-0601-00L Theory of Robotics and Mechatronics**

*This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.*

**Objective**
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Content**
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Lecture notes
available.

**151-0605-00L Nanosystems**

*This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.*

**Objective**
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Content**
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Lecture notes
available.
Abstract
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures. Special emphasis on the emerging field of molecular electronic devices.

Objective
Familiarize students with basic science and engineering principles governing the nano domain. The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Content
Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled. Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:
(I) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures.

Literature

Prerequisites
- Testing and characterization of the MEMS device
- Packaging and electrical connection of a MEMS device

Participating students are required to attend all scheduled lectures and meetings of the course.

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Participating students are required to provide proof that they have personal accident insurance prior to the start of the laboratory portion of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"
Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Profs Daraio, Dual, Hierold, Koumoutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

151-0911-00L Introduction to Plasmonics

Abstract
This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.
Combining knowledge in combinatorics with other fields such as algebraic methods.

Objective
Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Content
Multifunctional Ferroic Materials: Growth and Characterisation
- Basic electromagnetic theory
- Optical properties of metals
- Surface plasmon polaritons on surfaces
- Surface plasmon polariton propagation
- Localized surface plasmons

Applications of Plasmonics
- Waveguides
- Extraordinary optical transmission
- Enhanced spectroscopy
- Sensing
- Metamaterials

Lecture notes
Class notes and handouts

Literature

Prerequisites / notice
Physics I, Physics II

327-2132-00L Multifunctional Ferroic Materials: Growth and Characterisation

Abstract
The course will explore the growth of (multi-) ferroic oxide thin films. The structural characterization and ferroic state investigation by force microscopy and by laser-optical techniques will be addressed. Oxide electronics device concepts will be discussed.

Objective
Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal. Particularly interesting phenomena occur in films showing magnetic or electric order or, even better, both of these (“multiferroics”).

In this course students will obtain an overarching view on oxide thin epitaxial films and heterostructures design, reaching from their growth by pulsed laser deposition to an understanding of their magnetoelectric functionality from advanced characterization techniques. Students will therefore understand how to fabricate and characterize highly oriented films with magnetic and electric properties not found in nature.

Content
Types of ferroic order, multiferroics, oxide materials, thin-film growth by pulsed laser deposition, molecular beam epitaxy, RF sputtering, structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

363-0389-00L Technology and Innovation Management

Objective
This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change.

- understand the core concepts necessary to analyze how innovation happens
- master the most common methods and tools organizations deploy to innovate
- develop the ability to critically evaluate the innovation process, and act upon the main obstacles to innovation

Content
This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small.

How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, guest speakers, simulations and group work.

Lecture notes
Slides will be available on the Moodle page

Literature
Readings will be available on the Moodle page

Prerequisites / notice
The course content and methods are designed for students with some background in management and/or economics

401-3055-64L Algebraic Methods in Combinatorics

Abstract
Combining knowledge in combinatorics with other fields such as algebraic methods.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Lecture notes**
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

**Prerequisites / notice**
Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Energy and Power Electronics

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of "Energy and Power Electronics", see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

**Abstract**
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

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Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

**Content**
Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DCDC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with singe triangular carrier and individual carrier signals of the phases.

**Lecture notes**
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

**Prerequisites / notice**
Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

227-0517-10L Fundamentals of Electric Machines
- Type: W
- ECTS: 6 credits
- Hours: 4G
- Lecturers: D. Bortis

Abstract
This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective
The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

Content
- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes
Lecture notes and associated exercises including correct answers

Advanced Core Courses

Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0117-00L</td>
<td>High Voltage Engineering</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>C. Franck, U. Straumann</td>
</tr>
</tbody>
</table>

Abstract
High electric fields are used in numerous technological and industrial applications such as electric power transmission and distribution, X-ray devices, DNA sequencers, flue gas cleaning, power electronics, lasers, particle accelerators, copying machines, .... High Voltage Engineering is the art of gaining technological control of high electrical field strengths and high voltages. The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement. Further, they know the different insulation systems and their dimensioning in practice.

Objective
The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement.

Content
- discussion of the field equations relevant for high voltage engineering,
- analytical and numerical solutions/solving of this equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations
- introduction to kinetic gas theory
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components

Lecture notes
Lecture Slides

Literature
### Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: not assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0247-00L</td>
<td>Power Electronic Systems I</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>J. Biela, F. Krismer</td>
</tr>
<tr>
<td>227-0517-10L</td>
<td>Fundamentals of Electric Machines</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>D. Borris</td>
</tr>
<tr>
<td>227-0526-00L</td>
<td>Power System Analysis</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>G. Hug</td>
</tr>
</tbody>
</table>

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### Specialisation Courses

These specialisation courses are particularly recommended for the area of "Energy and Power Electronics", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
</tr>
</tbody>
</table>
Abstract
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

Objective
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

Content
1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

Lecture notes
Lecture Notes

227-0103-00L Control Systems

<table>
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<tr>
<th>Content</th>
<th>Objective</th>
<th>Abstract</th>
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</thead>
<tbody>
<tr>
<td>W 6 credits</td>
<td>2V+2U F. Dörlfler</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multifarious systems.</td>
</tr>
</tbody>
</table>

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

227-0121-00L Communication Systems

<table>
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<tr>
<th>Content</th>
<th>Objective</th>
<th>Abstract</th>
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</thead>
<tbody>
<tr>
<td>W 6 credits</td>
<td>4G A. Wittneben</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. Baseband Transmission, Passband Transmission, Example und Channel, Data Link Layer, MAC, Example Layer 2, Layer 3, Internet</td>
</tr>
</tbody>
</table>

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

227-0225-00L Linear System Theory

<table>
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<tr>
<th>Content</th>
<th>Objective</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 6 credits</td>
<td>5G A. Iannelli</td>
<td>The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of linear properties of control systems.</td>
</tr>
</tbody>
</table>

Literature

Prerequisites / notice
Available on the course Moodle platform.
Sufficient mathematical maturity, in particular in linear algebra, analysis.

227-0517-10L Fundamentals of Electric Machines

<table>
<thead>
<tr>
<th>Content</th>
<th>Objective</th>
<th>Abstract</th>
</tr>
</thead>
</table>

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.
This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes
Lecture notes and associated exercises including correct answers

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Organizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0523-00L</td>
<td>Railway Systems I</td>
<td>W</td>
<td>6 credits</td>
<td>M. Meyer</td>
</tr>
<tr>
<td>227-0536-00L</td>
<td>Multiphysics Simulations for Power Systems</td>
<td>W</td>
<td>4 credits</td>
<td>J. Smajic</td>
</tr>
</tbody>
</table>

Prerequisites / notice
Dozent: Dr. Markus Meyer, Emkamatik GmbH

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies

Domain D - Personal Competencies
- Critical Thinking

Geplante Exkursionen:
Betriebszentrale SBB, Zürich Flughafen
Reparatur und Unterhalt, SBB Zürich Altstetten
Fahrzeugfertigung, Stadler Bussnang

Voraussichtlich ein oder zwei Gastreferate

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahnninfrastruktur.

Taught competencies

Domain A - Subject-specific Competencies

Domain B - Method-specific Competencies

Domain D - Personal Competencies

227-0537-00L Technology of Electric Power System Components
**Objective**
The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL). After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

**Content**
1. **Electromagnetic Fields and Waves:** Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. **Finite Element Method for electromagnetic simulations** (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. **Practical applications** (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)

**227-0567-00L** Design of Power Electronic Systems

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Complete design process: from given specifications to a complete power electronic system: selection / design of suitable passive power components; static and dynamic properties of power semiconductors; optimized EMI filter design; heat sink optimization; additional circuitry, e.g. gate driver; system optimization.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Basic knowledge of design and optimization of a power electronic system; furthermore, lecture and exercises thoroughly discuss key subjects of power electronics that are important with respect to a practical realization, e.g. how to select suitable power components, to understand switching operations, calculation of high frequency losses, EMI filter design and realization, thermal considerations.</td>
</tr>
<tr>
<td>Content</td>
<td>Complete design process: from given specifications to a complete power electronic system: selection / design of suitable passive power components: specific properties, parasitic components, tolerances, high frequency losses, thermal considerations, reliability. Static and dynamic characteristics of power semiconductors. Optimized design of the EMI filter. Thermal characterization of the converter, optimized heat sink design. Additional circuitry: gate driver, measurement, control. Converter start up: typical sequence of events, circuitry required. Overall system optimization: identifying couplings between different components of the considered power electronic system, optimization targets and issues.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes and complementary exercises including correct answers.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Introductory course on power electronics.</td>
</tr>
</tbody>
</table>

**227-0618-00L** Modeling, Characterization and Reliability of Power Semiconductors

<table>
<thead>
<tr>
<th>Abstract</th>
<th>This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modelling of power semiconductors, as well as on the related built-in reliability strategies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.</td>
</tr>
<tr>
<td>Content</td>
<td>This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safe operating area, and junction temperature of the devices. The following section introduces the basic principles for electrical, thermal, and electro-thermal simulation of power semiconductors by Technology Computed Aided Design (TCAD) and compact modeling. Finally, procedures are methods are presented to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling. During the laboratory activities, selections of the experimental techniques presented in the lecture are demonstrated on the base of realistic examples. Furthermore, schematic power devices will be simulated by the students with advanced TCAD tools and circuit simulators.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts to the lecture (approx. 250 pp.).</td>
</tr>
</tbody>
</table>
| Literature | E. Ohno: "Introduction to Power Electronics"
B. Murari et al.: "Smart Power ICs"
B. J. Baliga: "Physics Modern Power Devices"
S. K. Ghandi: "Semiconductor Power Devices" |

**227-0697-00L** Industrial Process Control

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
</tr>
</tbody>
</table>
Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and
engineering. Differences and characteristics of discrete and process industries.
Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical
analysis and design of closed-loop control for the process industry.
Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text);
PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design,
function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Proflibus); Ergonomic design, safety (IEC61508) and
availability, supervision and diagnosis.
Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security.
Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.

Slides will be available as .PDF documents, see “Learning materials” (for registered students only)

References will be given at the end of individual lectures.

Prerequisites / notice
Exercises: Tuesday 15-16

Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on
IEC61131-3.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
<th>Credits</th>
<th>V</th>
<th>G</th>
<th>Prerequisites / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0731-00L</td>
<td>Power Market I - Portfolio and Risk Management</td>
<td></td>
<td>6</td>
<td></td>
<td>4G</td>
<td>D. Reichelt, G. A. Koeppel</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.</td>
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<td>Objective</td>
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<td>Content</td>
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<tr>
<td></td>
<td>1. Pan-European power market and trading</td>
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<td></td>
<td>1.1. Power trading</td>
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<td>1.2. Development of the European power markets</td>
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<td>1.3. Energy economics</td>
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<td>1.4. Spot and OTC trading</td>
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<td>1.5. European energy exchange EEX</td>
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<td>2. Market model</td>
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<td>2.1. Market place and organisation</td>
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<td>2.2. Balance groups / balancing energy</td>
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<td>2.3. Ancillary services</td>
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<td>2.4. Market for ancillary services</td>
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<td>2.5. Cross-border trading</td>
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<td>2.6. Capacity auctions</td>
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<td>3. Portfolio and Risk management</td>
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<td></td>
<td>3.1. Portfolio management 1 (introduction)</td>
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<td>3.2. Forward and futures contracts</td>
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<td>3.3. Risk management 1 (m2m, VaR, hpfc, volatility, cvaR)</td>
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<td>3.4. Risk management 2 (PaR)</td>
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<td>3.5. Contract valuation (HPFC)</td>
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<td>3.6. Portfolio management 2</td>
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<td>2.8. Risk Management 3 (enterprise wide)</td>
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<td>4. Energy &amp; Finance I</td>
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<td>4.1. Options 1 basics</td>
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<td>4.2. Options 2 hedging with options</td>
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<td></td>
<td>4.3. Introduction to derivatives (swaps, cap, floor, collar)</td>
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<td>4.4. Financial modelling of physical assets</td>
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<td>4.5. Trading and hydro power</td>
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<td>4.6. Incentive regulation</td>
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<td>Lecture notes</td>
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<td>Handouts of the lecture</td>
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<td>Prerequisites / notice</td>
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<td>1 excursion per semester, 2 case studies, guest speakers for specific topics.</td>
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<td>Course Moodle: <a href="https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636">https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636</a></td>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
<th>Credits</th>
<th>V</th>
<th>G</th>
<th>Prerequisites / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0759-00L</td>
<td>International Business Management for Engineers</td>
<td></td>
<td>3</td>
<td></td>
<td>2V</td>
<td>W. Hofbauer</td>
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<tr>
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<td>This course will be offered for the last time in fall 2021</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Globalization of markets increases global competition and requires enterprises to continuously improve their performance to sustainably survive. Engineers substantially contribute to the success of an enterprise provided they understand and follow fundamental international market forces, economic basics and operational business management.</td>
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<td>Objective</td>
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<td>The goal of the lecture is to get a basic understanding of international market mechanisms and their consequences for a successful enterprise. Students will learn by practical examples how to analyze international markets, competition as well as customer needs and how they convert into a successful portfolio an enterprise offers to the global market. They will understand the basics of international business management, why efficient organizations and effective business processes are crucial for the successful survival of an enterprise and how all this can be implemented.</td>
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<td>Content</td>
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<td>The first part of the course provides an overview about the development of international markets, the expected challenges and the players in the market. The second part is focusing on the economic aspects of an enterprise, their importance for the long term success and how to effectively manage an international business. Based on these fundamentals the third part of the course explains how an innovative product portfolio of a company can be derived from considering the most important external factors and which consequences in respect of product innovation, competitive product pricing, organization and business processes emerge. Each part of the course includes practical examples to demonstrate the procedure.</td>
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<td></td>
<td>Lecture notes</td>
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<td>A script is provided for this lecture.</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>The lecture will be held in three blocks each of them on a Saturday (starts on September 19, 2020). Each block will focus on one of the three main topics of the course. Between the blocks the students will work on specific case studies to deepen the subject matter. About two weeks after the third block a written examination will be conducted.</td>
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Systems and Control
The core courses and specialisation courses below are a selection for students who wish to specialise in the area of “Systems and Control”, see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor's approval.
### Core Courses

These core courses are particularly recommended for the field of "Systems and Control". You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

### Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<tr>
<td>Objective</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Signal and Systems Theory II.</td>
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</tbody>
</table>

### Advanced Core Courses

Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>A. Iannelli</td>
</tr>
<tr>
<td>Abstract</td>
<td>The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.</td>
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<tr>
<td>Objective</td>
<td>Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems. - Proof techniques and practices. - Linear spaces, normed linear spaces and Hilbert spaces. - Ordinary differential equations, existence and uniqueness of solutions. - Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case. - Controllability and observability, duality. Time invariant systems treated as a special case. - Stability and stabilization, observers, state and output feedback, separation principle.</td>
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<tr>
<td>Content</td>
<td>notions</td>
<td>Lecture notes</td>
<td>Available on the course Moodle platform.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Sufficient mathematical maturity, in particular in linear algebra, analysis.</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td></td>
<td>Domain D - Personal Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Integration and Work Ethics</td>
<td>not assessed</td>
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<tr>
<td>227-0697-00L</td>
<td>Industrial Process Control</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Horch, M. Mercangöz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing. Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry. Automation Engineering; Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis. Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing. Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.</td>
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<tr>
<td>Objective</td>
<td>General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
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<tr>
<td>Content</td>
<td>Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries.</td>
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<tr>
<td>Literature</td>
<td>Slides will be available as .PDF documents, see &quot;Learning materials&quot; (for registered students only)</td>
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<tr>
<td>Prerequisites / notice</td>
<td>References will be given at the end of individual lectures.</td>
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<tr>
<td>Exercices</td>
<td>Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.</td>
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<tr>
<td>151-0371-00L</td>
<td>Advanced Model Predictive Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>M. Zeilinger, A. Carron, L. Hewing, J. Köhler</td>
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<tr>
<td>Number of participants limited to 60.</td>
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Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

Content
Topics include:
- Review of Bayesian statistics, stochastic systems and Stochastic Optimal Control
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites / notice
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control) strongly recommended. Background in linear algebra and stochastic systems recommended.

151-0563-01L Dynamic Programming and Optimal Control
W 4 credits 2V+1U R. D’Andrea
Abstract
Introduction to Dynamic Programming and Optimal Control.
Objective
Covers the fundamental concepts of Dynamic Programming & Optimal Control.
Content
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature

Prerequisites / notice
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

Specialisation Courses
These specialisation courses are particularly recommended for the area of “Systems and Control”, but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the Master's Programme.

Number Title Type ECTS Hours Lecturers
227-0102-00L Discrete Event Systems W 6 credits 4G R. Jacob, L. Vanbever, R. Wattenhofer
Abstract
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.

Objective
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content
1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes
Available
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

**Prerequisites / notice**

Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

**Lecture notes**

Course material, Script, computer demonstrations, exercises and problem solutions.
Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology. A more advanced Part II of this class is offered every other year.

System Identification

Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective
To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content
Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.

Additional papers will be available via the course Moodle.

Cell and Molecular Biology for Engineers I

This course is part I of a two-semester course.

Abstract
The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Objective
After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content
Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication.

These written documents will be graded and count as 40% for the final grade.

Nonlinear Dynamics and Chaos I

Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.
Content

(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.

(2) Near equilibrium dynamics: Linear and Lyapunov stability

(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations

(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.

(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes

The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice

- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

151-0573-00L  System Modeling  W  4 credits  2V+1U  L. Guzzella

Abstract

Introduction to system modeling for control. Generic modeling approaches based on first principles, Lagrangian formalism, energy approaches and experimental data. Model parametrization and parameter estimation. Basic analysis of linear and nonlinear systems.

Objective

Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.

Content

This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronic, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.

Lecture notes

The handouts in English will be available in digital form.

Literature

A list of references is included in the handouts.

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies

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

Domain D - Personal Competencies

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

151-0560-00L  Theory of Robotics and Mechatronics  W  4 credits  3G  P. Korba, S. Stoeter

Abstract

This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Objective

Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Content

An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Lecture notes

Available.

151-0563-01L  Dynamic Programming and Optimal Control  W  4 credits  2V+1U  R. D’Andrea

Abstract

Introduction to Dynamic Programming and Optimal Control.

Objective

Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content

Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature


Prerequisites / notice

376-1219-00L  Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions  W  3 credits  2V  R. Rieiner, O. Lamberty

Abstract

Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative systems.

Objective

Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Content

- Rehabilitation of visual function
  - Anatomy and physiology of the visual sense
  - Technical aids (glasses, sensor substitution)
  - Retina and cortex implants
  - Rehabilitation of hearing function
  - Anatomy and physiology of the auditory sense
  - Hearing aids
  - Cochlea Implants
  - Rehabilitation and use of kinesthetic and tactile function
  - Tactile/haptic displays for motion therapy (incl. electrical stimulation)
  - Role of displays in motor learning
  - Rehabilitation of vestibular function
  - Anatomy and physiology of the vestibular sense
  - Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
  - Cardiac Pacemaker
  - Phrenic stimulation, artificial breathing aids
  - Bladder stimulation, artificial sphincter
  - Brain stimulation and recording
  - Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature

Introductory Books:


Selected Journal Articles and Web Links:


Prerequisites / notice

Target Group:
- Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

401-0647-00L Introduction to Mathematical Optimization W 5 credits 2V+1U D. Adjiashvili

### Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

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

### Content
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

### Literature
Information about relevant literature will be given in the lecture.

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

### 401-3901-00L
**Linear & Combinatorial Optimization**

- **W**
- **11 credits**
- **4V+2U**
- **R. Zenklusen**

#### Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

#### Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

#### Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

#### Literature

#### Prerequisites / notice
Solid background in linear algebra.

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### 636-0007-00L
**Computational Systems Biology**

- **W**
- **6 credits**
- **3V+2U**
- **J. Stelling**

#### Abstract
Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modelling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

#### Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

#### Content
Biological systems are complex and dynamic. The aim of the course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks. We will start with an introduction into the basic units, functions and design principles that are relevant for biological systems. We will then focus on methods and algorithms that are used for the investigation of biological networks with increasing detail. This includes (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

#### Literature
- Equivalence between optimization and separation.

---

### 401-3055-64L
**Algebraic Methods in Combinatorics**

- **W**
- **6 credits**
- **2V+1U**
- **B. Sudakov**

#### Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.
### Signal Processing and Machine Learning

The core courses and specialisation courses below are a selection for students who wish to specialise in the area of “Signal Processing and Machine Learning”, see https://www.ee.ethz.ch/studies/main-master/areas-of-specialisation.html.

The individual study plan is subject to the tutor’s approval.

#### Core Courses

These core courses are particularly recommended for the field of “Signal Processing and Machine Learning”. You may choose core courses form other fields in agreement with your tutor.

A minimum of 24 credits must be obtained from core courses during the MSc EEIT.

#### Foundation Core Courses

Fundamentals at bachelor level, for master students who need to strengthen or refresh their background in the area.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0101-00L</td>
<td>Discrete-Time and Statistical Signal Processing</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.</td>
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<tr>
<td>Objective</td>
<td>The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust “inversion” of a linear filter.</td>
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</tr>
<tr>
<td>Content</td>
<td>1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.</td>
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<tr>
<td></td>
<td>2. The discrete Fourier transform and its use for digital filtering,</td>
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<td></td>
<td>3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture Notes</td>
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<tr>
<th>Number</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<tr>
<td>Objective</td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<td></td>
</tr>
<tr>
<td>Content</td>
<td>Review of probability theory; basics of statistical estimation; least squares and linear learning; Hilbert spaces; Gaussian random variables; singular-value decomposition; kernel methods, neural networks, and more.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes will be handed out as the course progresses.</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>solid basics in linear algebra and probability theory</td>
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</tbody>
</table>

#### Advanced Core Courses

Advanced core courses bring students to gain in-depth knowledge of the chosen specialization. They are MSc level only.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td>Abstract</td>
<td>The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.</td>
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</tbody>
</table>
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### Lecture notes
Detailed lecture notes are available on the course web page: [https://www.mins.ee.ethz.ch/teaching/intnt/](https://www.mins.ee.ethz.ch/teaching/intnt/)

### Prerequisites / notice
This course is replaced by "Introduction to Estimation and Machine Learning" and "Advanced Signal Analysis, Modeling, and Machine Learning".

### Objective
The course is an introduction to some basic topics in signal processing and machine learning.

### Content
Part I - Linear Signal Representation and Approximation; Hilbert spaces, least squares and LMMSE estimation, projection and estimation by linear filtering, learning linear functions and filters, L2 regularization, L1 regularization and sparsity, singular-value decomposition and pseudo-inverse, principal-components analysis.


### Lecture notes
Lecture notes.

### Prerequisites / notice
- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

### 227-0427-00L Signal Analysis, Models, and Machine Learning

| Objective | After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks. |
| Content | 1. Universal approximation with single- and multi-layer networks  
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory  
3. Fundamental limits of deep neural network learning  
4. Geometry of decision surfaces  
5. Separating capacity of nonlinear decision surfaces  
6. Vapnik-Chervonenkis (VC) dimension  
7. VC dimension of neural networks  
8. Generalization error in neural network learning |
| Lecture notes | Detailed lecture notes are available on the course web page [https://www.mins.ee.ethz.ch/teaching/intnt/](https://www.mins.ee.ethz.ch/teaching/intnt/) |
| Prerequisites / notice | This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular. |

### 227-0447-00L Image Analysis and Computer Vision

| Objective | Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises. |
| Content | This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given. |
| Lecture notes | Course material Script, computer demonstrations, exercises and problem solutions |
| Prerequisites / notice | Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. |

### 252-0535-00L Advanced Machine Learning

| Objective | Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data. |
| Abstract | Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects. |
| Lecture notes | Course material Script, computer demonstrations, exercises and problem solutions |
| Prerequisites / notice | The course language is English. |
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
- What is data?
- Bayesian Learning
- Computational learning theory

Supervised learning:
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

Unsupervised learning:
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

**263-3210-00L Deep Learning**

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://mi2.inf.ethz.ch/courses/stt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

**401-4944-20L Mathematics of Data Science**

Abstract
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective
Introduction to various mathematical aspects of Data Science.

Content
These topics lie in overlaps of (Applied) Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Each lecture will feature a couple of Mathematical Open Problem(s) related to Data Science. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

Lecture notes
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and “227-0434-10L Mathematics of Information” taught by Prof. H. Bölcskei. The two courses are designed to be complementary. A. Bandeira and H. Bölcskei

Specialisation Courses

These specialisation courses are particularly recommended for the area of "Signal Processing and Machine Learning", but you are free to choose courses from any other field in agreement with your tutor.

A minimum of 40 credits must be obtained from specialisation courses during the MSc EEIT.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL based design for FPGAs</td>
<td>W</td>
<td>6 credits</td>
<td>5G</td>
<td>F. K. Gürkaynak, L. Benini</td>
</tr>
</tbody>
</table>

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature

Prerequisites / notice
Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

| 227-0155-00L | Machine Learning on Microcontrollers | W    | 6 credits | 3G    | M. Magno, L. Benini |

Registration in this class requires the permission of the instructors. Class size will be limited to 25. Preference is given to students in the MSc EEIT.

Abstract
Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly "smart". This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the "internet-of-things", using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V).

Objective
Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercises will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

Prerequisites / notice


Lecture notes

Script and exercise sheets. Books will be suggested during the course.

Content

227-0121-00L Communication Systems W 6 credits 4G A. Wittneben

Abstract

Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems

Objective

The application of the basic methods will be extensively explained using existing and future wireless and wired systems.

Content

Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.

Lecture notes

Lecture Slides

Literature


227-0225-00L Linear System Theory W 6 credits 5G A. Ianneli

Abstract

The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Objective

Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes

Available on the course Moodle platform.

Prerequisites / notice

Sufficient mathematical maturity, in particular in linear algebra, analysis.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Domain D - Personal Competencies
Creative Thinking
Critical Thinking
Integrity and Work Ethics

227-0417-00L Information Theory I W 6 credits 4G A. Lapidoth

Abstract

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Content

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Literature

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

227-0421-00L Deep Learning in Artificial and Biological Neuronal Networks W 4 credits 3G B. Grewe

Abstract

Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

After this course students will be able to:
- understand the basics of Bayesian learning (Gaussian processes, Bayesian deep learning)
- understand and implement alternative ANN learning algorithms to 'error backpropagation'
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.
- understand the use of measuring instruments.
- understand and implement alternative ANN learning algorithms to 'error backpropagation'.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

After this course students will be able to:
- understand and implement alternative ANN learning algorithms to 'error backpropagation'.
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.
- understand the use of measuring instruments.
- understand and implement alternative ANN learning algorithms to 'error backpropagation'.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

After this course students will be able to:
- understand and implement alternative ANN learning algorithms to 'error backpropagation'.
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.
- understand the use of measuring instruments.
- understand and implement alternative ANN learning algorithms to 'error backpropagation'.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.
Objective
This course aims to provide students with an advanced introduction of RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, students will be able to
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover “new” applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

Content
Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

Lecture notes
Lecture notes will be posted on Moodle.

Literature
Dynamic Programming and Optimal Control, Vol I & II, Dimitris Bertsekas
Algorithms for Reinforcement Learning, Csaba Czepesvári.

Prerequisites / notice
Students are expected to have a strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

401-3055-64L Algebraic Methods in Combinatorics W 6 credits 2V+1U B. Sudakov
Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):
- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757
Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

401-3621-00L Fundamentals of Mathematical Statistics W 10 credits 4V+1U S. van de Geer
Abstract
The course covers the basics of inferential statistics.

401-3901-00L Linear & Combinatorial Optimization W 11 credits 4V+2U R. Zenklusen
Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Electives

This is only a short selection. Other courses from the ETH course catalogue may be chosen in agreement with your tutor.

As an alternative to the elective courses, students may do a second semester project or an internship in industry. Please consult your tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0371-00L</td>
<td>Advanced Model Predictive Control</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>M. Zeilinger, A. Carron, L. Hewing, J. Köhler</td>
</tr>
</tbody>
</table>

Abstract
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

Objective
- Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.
- MPC as safety filter for reinforcement learning
- Bayesian regression and stochastic data-driven MPC
- Nominal MPC for uncertain systems (nominal robustness)
- Stochastic MPC
- Set-membership identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

Lecture notes
Lecture notes will be provided.

Prerequisites / notice
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control) strongly recommended.

Background in linear algebra and stochastic systems recommended.

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<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>363-0511-00L</td>
<td>Managerial Economics</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>V. Lohmann, P. Egger, M. Köthenbürger</td>
</tr>
</tbody>
</table>

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective
- The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature

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<tr>
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</table>

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. broaden understanding of management principles and frameworks
2. advance insights into the sources of corporate and entrepreneurial success
3. develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.
The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

During the course, students will learn about different design thinking methods and tools. This will enable them to:

- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.
- Engage in collaborative ideation with a multidisciplinary team.
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).

These course materials will form the point of departure for the lectures, class discussions and team work.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

Complementary exercises for the module Discovering Management.

Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

Abstract

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Content

Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management.

Students have the option to either write this alone or in a group of two students.

Literature

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Problem-solving
Communication
Self-presentation and Social Influence
Creative Thinking
Critical Thinking

Domain B - Method-specific Competencies
Concepts and Theories
Analytical Competencies
Problem-solving
Communication

Domain C - Social Competencies

Domain D - Personal Competencies

363-0790-00L Technology Entrepreneurship

W 2 credits 2V F. Hacklin

Abstract

Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

Objective

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Content

See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

Lecture notes

Lecture slides and case material

363-1065-00L Design Thinking: Human-Centred Solutions to Real World Challenges

W 5 credits 5G S. Brusoni

Abstract

Does not take place this semester.

The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Information and application: http://sparklabs.ch/

Objective

During the course, students will learn about different design thinking methods and tools. This will enable them to:

- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validated them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session. Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

363-1082-00L Enabling Entrepreneurship: From Science to Startup

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 40. It is preferable that the students already form teams of at least two persons, where both the team-members would like to do the course. The names of the team-members should be provided together with the business idea or the motivation letter submitted by the students.

The students should submit the necessary information until September 13 and apply to anilsethi@ethz.ch

Objective

Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs
2. The students can be from business or science & technology
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea

Content

The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay
8. Legal overview, company forms and shareholders' agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes

Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Literature

Book

Sethi, A. “From Science to Startup”
ISBN 978-3-319-30422-9
This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don’t have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

**Prerequisites / notice**

- Students shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall be familiar with the issues of corporate compliance, i.e. the system to ascertain that all legal and ethical rules are observed.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall have an understanding of the law of the EU and into criminal law.

**Taught competencies**

**Domain B - Method-specific Competencies**

- Media and Digital Technologies
- Project Management

**Domain C - Social Competencies**

- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility

**Domain D - Personal Competencies**

- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection
- Self-direction and Self-management

**851-0703-00L Introduction to Law**

*Students who have attended or will attend the lecture “Introduction to Law for Civil Engineering and Architecture” (851-0703-03L) or “Introduction to Law” (851-0708-00L), cannot register for this course unit.*

**Abstract**

This class introduces students to basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.

**Objective**

Students are able to identify basic structures of the legal system. They understand selected topics of public and private law and are able to apply the fundamentals in more advanced law classes.

**Content**

- Basic concepts of law, sources of law.
- Private law: Contract law (particularly contract for work and services), tort law, property law.
- Public law: Human rights, administrative law, procurement law, procedural law.
- Insights into the law of the EU and into criminal law.

**Lecture notes**

Jaap Hage, Bram Akkermans (Eds.), *Introduction to Law*, Cham 2017 (Online Resource ETH Library)

**Literature**

Further documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15142).

**851-0735-10L Business Law**

*Number of participants limited to 100*  

**Abstract**

The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.

**Objective**

The students shall obtain the following competence:
- They shall have an understanding of the law of the EU and into criminal law.
- They shall have a basic understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**

A comprehensive script will be made available online on the moodle platform.

**851-0738-00L Intellectual Property: Introduction**

*Particularly suitable for students of D-CHAB, D-INFK, D-ITET, D-MAVT, D-MATL, D-MTEC*

**Abstract**

The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated as far as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

**Objective**

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

**851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector**

*Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT*

**Abstract**

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.
Objective

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

Prerequisites / notice

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

II. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.

III. Learning linear and nonlinear functions and filters: neural networks, kernel methods.

II. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.

III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.

Master Studies (Programme Regulations 2008)

Communication

These core subjects are particularly recommended for the field of "Communication".

Objective

The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Content

- Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
- Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
- Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
- Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
- Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes

Lecture notes are handed out.

Literature


Notice

This course was replaced by "Introduction to Estimation and Machine Learning" and "Advanced Signal Analysis, Modeling, and Machine Learning".

Signal Analysis, Models, and Machine Learning

Does not take place this semester.

Mathematical methods in signal processing and machine learning.

I. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.

II. Learning linear and nonlinear functions and filters: neural networks, kernel methods.

III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.
The course is an introduction to some basic topics in signal processing and machine learning.

### Objective
The general learning goals of the course: By the end of this course, students will be able to

- understand and illustrate the physical layer and MAC layer limits and challenges of wireless systems with emphasis on data communication and localization
- understand and explain the functioning of the most widely used wireless systems
- model and simulate the physical layer of state-of-the-art wireless systems
- explain challenges and solutions of indoor localization
- understand research challenges of future wireless networks

### Content
Specific learning goals include:

- Understanding the principles of OFDM and analyzing its performance on the physical layer
- Understanding and evaluating the challenges regarding current applications of wireless networks, e.g., for the Internet-of-things, smart grid communication, biomedical sensor communication
- Illustrating the characteristics of the wireless channel
- Simulation of localization and user tracking based on wireless systems
- Explaining the basics of smart grid communications approaches (including narrowband PLC, G3-PLC)

The course consists of two parallel tracks. The track “Technology & Systems” is structured as regular lecture. In the introduction, we discuss the challenges and potential of wireless access and study some fundamental limits of wireless communications and localization approaches.

The second part of this track is devoted to the most widely used wireless systems, WiFi/WLAN, Bluetooth, RFID, NFC. Furthermore, we study the potential of using existing wireless communication systems for indoor localization.

The third part follows with an introduction to the Internet-of-things, where we focus on data communication and localization challenges and solutions in wireless networks with a massive number of nodes. Next, we study communication technologies for the smart grid, which combine wireless as well as power line communication approaches to optimize availability and efficiency.

The track is completed by a comprehensive survey of short-range magneto-inductive micro sensor networks for communication and localization - as a promising technology for biomedical sensor communication (in-body, out-of-body).

In the track “Simulate & Practice” we form student teams to simulate and analyze functional blocks of the physical layer of advanced wireless systems (based on MATLAB simulations). The track includes combination tasks in which different teams combine their functional blocks (e.g., transmitter, receiver) in order to simulate the complete physical layer of a wireless system. The focus is on data communication and localization. The tasks include modeling and simulating of single-carrier systems (as, e.g., used in Bluetooth), multi-carrier OFDM systems (e.g. used in WiFi or power line communication), and indoor localization approaches (e.g. relevant for IoT and sensor networks).

### Literature
- **Recommended Subjects**

  These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.

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<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>R. Jacob, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

### Lecture notes
Lecture notes.

### Prerequisites / notice
Prerequisites:
- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

### Prerequisites / literature
**Recommended Subjects**

These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.

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<tr>
<td>227-0439-00L</td>
<td>Wireless Access Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>A. Wittneben</td>
</tr>
</tbody>
</table>

Does not take place this semester.

### Prerequisites / notice
Prerequisites:
- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

### Lecture notes
Lecture notes.

### Prerequisites / literature
Important topics are broadband data networks, indoor localization, Internet-of-things, biomedical sensor networks and smart grid communications. The course consists of two tracks, the lecture part “Technology & Systems” and the group exercise part “Simulate & Practice”.

### Prerequisites / notice
The course consists of two parallel tracks. The track “Technology & Systems” is structured as regular lecture. In the introduction, we discuss the challenges and potential of wireless access and study some fundamental limits of wireless communications and localization approaches.

The second part of this track is devoted to the most widely used wireless systems, WiFi/WLAN, Bluetooth, RFID, NFC. Furthermore, we study the potential of using existing wireless communication systems for indoor localization.

The third part follows with an introduction to the Internet-of-things, where we focus on data communication and localization challenges and solutions in wireless networks with a massive number of nodes. Next, we study communication technologies for the smart grid, which combine wireless as well as power line communication approaches to optimize availability and efficiency.

The track is completed by a comprehensive survey of short-range magneto-inductive micro sensor networks for communication and localization - as a promising technology for biomedical sensor communication (in-body, out-of-body).

In the track “Simulate & Practice” we form student teams to simulate and analyze functional blocks of the physical layer of advanced wireless systems (based on MATLAB simulations). The track includes combination tasks in which different teams combine their functional blocks (e.g., transmitter, receiver) in order to simulate the complete physical layer of a wireless system. The focus is on data communication and localization. The tasks include modeling and simulating of single-carrier systems (as, e.g., used in Bluetooth), multi-carrier OFDM systems (e.g. used in WiFi or power line communication), and indoor localization approaches (e.g. relevant for IoT and sensor networks).

### Lecture notes
Lecture slides are available.

### Prerequisites / notice
Will be announced in the lecture.

### Recommended Subjects

These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>R. Jacob, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

### Abstract
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.
Objective
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content
1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes
Available

Literature
[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[borodin] Online Computation and Competitive Analysis
Allan Borodin, Ran El-Yaniv.
Cambridge University Press, 1998

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune.

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger

D. Hochbaum

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser.

227-0103-00L Control Systems  W  6 credits  2V+2U  F. Dörfler

Abstract
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objectives
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content
Process automation, concept of control. Modelling of dynamical systems - examples, state space description, linearisation.

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

227-0116-00L VLSI 1: HDL based design for FPGAs  W  6 credits  5G  F. K. Gürkaynak, L. Benini

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Textbook and all further documents in English.


During the first weeks of the course there will be weekly practical exercises where you will work in groups of two. For the last 5 weeks of the course students will be able to choose a class project that can be:

- The test of their own chip developed during a previous semester thesis
- Developing new setups and measurement methods in C++ on the tester
- Helping to debug problems encountered in previous microchips by IIS.

Half of the oral exam will consist of a short presentation on this class project.

Handouts of presented slides. No script but an accompanying textbook is recommended.


Autumn Semester 2021

6 credits

6 credits
### Optical Communication Fundamentals

**Abstract**
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

**Objective**
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed on. Students attending the lecture will further get engaged in critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

**Content**

- Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
- Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
- Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
- Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
- Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

**Lecture notes**
Lecture notes are handed out.

**Literature**

**Prerequisites / notice**

### Neural Network Theory

**Abstract**
The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

**Objective**
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

**Content**

1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

**Lecture notes**
Detailed lecture notes are available on the course web page [https://www.mins.ee.ethz.ch/teaching/nnt/](https://www.mins.ee.ethz.ch/teaching/nnt/)

**Prerequisites / notice**
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### Image Analysis and Computer Vision

**Abstract**
Light and perception. Digital image formation. Image enhancement and feature extraction. Unitary transformations. Color and texture. Image Analysis and Computer Vision

**Objective**
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

**Content**

- Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
- Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
- Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
- Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
- Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

**Lecture notes**
Lecture notes are handed out.

**Literature**

**Prerequisites / notice**
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups. The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements this lecture very well in that respect.

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes, and a Python-based open-source tool to manipulate graphs is available on https://github.com/haschmid/signallowgrapher

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

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

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Prerequisites / notice

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensible to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

| 263-4640-00L | Network Security | 8 credits | 2V+2U+3A | A. Perrig, S. Frei, M. Legner, K. Paterson |

Abstract
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective
- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Domain B - Method-specific Competencies**
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

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

**Domain D - Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management
We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack.

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Prerequisites / notice

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Leaders are expected to have a mathematical background and should be able to write rigorous proofs.


Abstract

This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals are to learn how to design digital circuits on the schematic, layout, and gate levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

Objective

At the end of this course you will
- understand how the main building blocks of state-of-the-art digital integrated circuits are designed
- be able to analyze and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between speed, area, and power consumption

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:

- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Literature

W. H. E. Weste and D. M. Harris, CMOS VLSI Design: A Circuits and Systems Perspective (4th Ed.), Addison-Wesley

Prerequisites / notice

VL313 can be taken in parallel with “VL311: HDL based design for FPGAs” and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

Computers and Networks

Core Subjects

These core subjects are particularly recommended for the field of “Computers and Networks”.

Number Title Type ECTS Hours Lecturers

227-2210-00L Computer Architecture W 8 credits 6G+1A O. Mutlu

Abstract

Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

Objective

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc.

Content

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

Lecture notes

All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/
Advanced Topics in Communication Networks

**Abstract**
This course covers advanced topics and technologies in computer networks, both theoretically and practically. It is offered each Fall semester, with rotating topics. Repetition for credit is possible with consent of the instructor. In the Fall 2021, the course will cover advanced topics in Internet routing and forwarding. The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet routing and forwarding technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments, and even implement some of them on their own during labs and a final group project.

**Objective**
The course will cover advanced topics in Internet routing and forwarding such as:
- Tunneling
- Hierarchical routing
- Traffic Engineering and Load Balancing
- Virtual Private Networks
- Quality of Service/Queuing/Scheduling
- Fast Convergence
- Network virtualization
- Network programmability (OpenFlow, P4)
- Network measurements

The course will be divided into two main blocks. The first block (~8 weeks) will interleave classical lectures with practical exercises and labs. The second block (~6 weeks) will consist of a practical project which will be performed in small groups (~3 students). During the second block, lecture slots will be replaced by feedback sessions where students will be able to ask questions and get feedback about their project. The last week of the semester will be dedicated to student presentations and demonstrations.

**Literature**
Lecture notes and material will be made available before each course on the course website.

**Prerequisites / notice**
Prerequisites:

- Communication Networks (227-0120-00L) or equivalents
- Good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

**Domain A - Subject-specific Competencies**

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<tr>
<th>Competency</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Communication</th>
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**Domain B - Method-specific Competencies**

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**Domain C - Social Competencies**

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**Domain D - Personal Competencies**

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<th>Competency</th>
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**Hardware Security**

This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures, reviewing and discussing papers, and executing some of these advanced attacks.

**Objective**
By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:
- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

**Literature**
Slides, relevant literature and manuals will be made available during the course.

**Prerequisites / notice**
Knowledge of systems programming and computer architecture is a plus.

**System Security**

The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

**Objective**
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

**Content**
The first part of the lecture covers individual system's aspects starting with tamperproof or tamperresistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

**Network Security**

This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures, reviewing and discussing papers, and executing some of these advanced attacks.

**Objective**
By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:
- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

**Literature**
Slides, relevant literature and manuals will be made available during the course.

**Prerequisites / notice**
Knowledge of systems programming and computer architecture is a plus.
Communication
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of
network-security protocols based on cryptographic libraries.

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. Discrete-time linear systems and filters:
   - Students can implement network-security protocols based on cryptographic libraries.

2. The discrete Fourier transform and its use for digital filtering.
   - Students have an in-depth understanding of a range of important state-of-the-art security technologies.

3. The statistical perspective:
   - Students can identify and assess vulnerabilities in software systems and network protocols.

   - Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are
assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L.

Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview
of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network
programming language such as C/C++, Go, Python, or Rust.

Content

Literature

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.
MATLAB is used for system analysis and simulation.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL based design for FPGAs</td>
<td>6 credits</td>
<td>W</td>
<td>F. K. Gürkaynak, L. Benini</td>
</tr>
</tbody>
</table>

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with deising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature

227-0377-10L

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Audience</th>
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</thead>
<tbody>
<tr>
<td>227-0377-10L</td>
<td>Physics of Failure and Reliability of Electronic Devices and Systems</td>
<td>3 credits</td>
<td>W</td>
<td>I. Shorubalko, M. Held</td>
</tr>
</tbody>
</table>

Abstract
Understanding the physics of failures and failure mechanisms enables reliability analysis and serves as a practical guide for electronic devices design, integration, systems development and manufacturing. The field gains additional importance in the context of managing safety, sustainability and environmental impact for continuously increasing complexity and scaling-down trends in electronics.

Objective
Provide an understanding of the physics of failure and reliability. Introduce the degradation and failure mechanisms, basics of failure analysis, methods and tools of reliability testing.

Content
Summary of reliability and failure analysis terminology; physics of failure: materials properties, physical processes and failure mechanisms; failure analysis; basics and properties of instruments; quality assurance of technical systems (introduction); introduction to stochastic processes; reliability analysis; component selection and qualification; maintainability analysis (introduction); design rules for reliability, maintainability, reliability tests (introduction).

Lecture notes
Comprehensive copy of transparencies

Literature

227-0447-00L

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>227-0447-00L</td>
<td>Image Analysis and Computer Vision</td>
<td>6 credits</td>
<td>W</td>
<td>L. Van Gool, E. Konukoglu, F. Yu</td>
</tr>
</tbody>
</table>

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter includes the main models of fault-tolerant distributed systems (crash failures, Byzantine failures, and selfishness), and the most important algorithms, protocols and impossibility results. By the end of the course, students should be able to reason about various concepts such as consistency, durability, availability, fault tolerance, and replication.

The course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc.

The course includes the main models of fault-tolerant distributed systems (crash failures, Byzantine failures, and selfishness), and the most important algorithms, protocols and impossibility results. By the end of the course, students should be able to reason about various concepts such as consistency, durability, availability, fault tolerance, and replication.

The course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc.

This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. graph analytics, bioinformatics, machine learning), etc., and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

The video recordings of the lectures are expected to be made available after lectures.

This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

The course takes place in roughly the second half of the semester, as the lecture is the second part of the lecture "Computer Systems" (252-0217-00). Students may attend at most one of the two lectures, NOT both.

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marisnm@ethz.ch)

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html
### 252-1411-00L Security of Wireless Networks

**W** 6 credits  2V+1U+2A  S. Capkun, K. Kostiainen

**Abstract**
Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.

**Objective**
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless networks and systems: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

**Content**

### 401-3055-64L Algebraic Methods in Combinatorics

**W** 6 credits  2V+1U  B. Sudakov

**Abstract**
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic combinatorial arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Lecture notes**
Lectures will be on the blackboard only, but there will be a set of typed course notes which follow the class closely.

**Prerequisites / notice**
Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Electronics and Photonics

#### Core Subjects

These core subjects are particularly recommended for the field of "Electronics and Photonics".

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0146-00L</td>
<td>Analog-to-Digital Converters</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**
This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation.

**Objective**
Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. The student will learn to understand the basic principles behind data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained with their principle of operation accompanied with the appropriate mathematical calculations, including the effects of non-idealities in some cases. After successful completion of the course the student should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.

**Content**

- Introduction: information representation and communication; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.

- Dual-slope & successive approximation register (SAR) converters; dual-slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array.

- Arithmetic & pipelined A/D converters; algorithmic conversion principle; sample & hold stage; pipe-lined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealities, error correction.

- Performance metrics and non-linearity; ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.

- Flash, folding an interpolating analog-to-digital converters; flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.

- Noise in analog-to-digital converters; types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.

- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.


**Lecture notes**
Slides are available online under https://isis-students.ee.ethz.ch/lectures/analog-to-digital-converters/

**Literature**
- M. Gustavsson et. al., CMOS Data Converters for Communications, Springer, 2010

**Prerequisites / notice**
It is highly recommended to attend the course "Analog Integrated Circuits" of Prof. T. Jang as a preparation for this course.


**Abstract**
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals are to learn how to design digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:

- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

Lecture notes are handed out.

227-0148-00L VLSI III: Test and Fabrication of VLSI Circuits

W 6 credits 4G L. Benini

Does not take place this semester.

Content
In this course, we will cover how modern microchips are fabricated, and we will focus on methods and tools to uncover fabrication defects, if any, in these microchips. As part of the exercises, students will get to work on an industrial 1 million dollar automated test equipment.

Prerequisites / notice
VLSI3 can be taken in parallel with "VLSI1: HDL based design for FPGAs" and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

227-0301-00L Optical Communication Fundamentals

W 6 credits 2V+1U+1P J. Leuthold

Abstract
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the important elements will be passed. Students attending the lecture will further get pieces in a critical discussion on societal, economical and environmental aspects related to the on-going exponential growth in the field of communications.

Content
- Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


- Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.

- Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.

- Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.

- Chapter 7: Optical Amplifiers: Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes
Lecture notes are handed out.
### Fundamentals of Electric Machines

**W** 6 credits 4G  D. Bortis

**Abstract**
This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

**Objective**
The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

**Content**
- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

**Lecture notes**
Lecture notes and associated exercises including correct answers

### Nano-Optics

**W** 6 credits 2V+2U  M. Frimmer

**Abstract**
Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied research enabled by the rapid advance of nanotechnology. Nano-optics embraces topics such as plasmonics, optical antennas, optical trapping and manipulation, and high/super-resolution imaging and spectroscopy.

**Objective**
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

**Content**
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

**Prerequisites / notice**
- Electromagnetic fields and waves (or equivalent)
- Physics I+II

### Nonlinear Optics

**W** 6 credits 2V+2U  J. Leuthold

**Abstract**
Nonlinear Optics deals with the interaction of light with material, the response of material to light and the mathematical framework to describe the phenomena. As an example we will cover fundamental phenomena such as the refractive index, the electro-optic effect, second harmonic generation, four-wave mixing or soliton propagation and others.

**Objective**
The important nonlinear optical phenomena are understood and can be classified. The effects can be described mathematical by means of the susceptibility.

**Content**
Chapter 1: The Wave Equations in Nonlinear Optics
Chapter 2: Nonlinear Effects - An Overview
Chapter 3: The Nonlinear Optical Susceptibility
Chapter 4: Second Harmonic Generation
Chapter 5: The Electro-Optic Effect and the Electro-Optic Modulator
Chapter 6: Acousto-Optic Effect
Chapter 7: Nonlinear Effects of Third Order
Chapter 8: Nonlinear Effects in Media with Gain

**Literature**
Lecture notes are distributed. For students enrolled in the course, additional information, lecture notes and exercises can be found on moodle (https://moodle-app2.let.ethz.ch/).

**Prerequisites / notice**
Fundamentals of Electromagnetic Fields (Maxwell Equations) & Bachelor Lectures on Physics

### Neuromorphic Engineering I

**W** 6 credits 2V+3U  T. Delbrück, G. Indiveri, S.-C. Liu

**Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.**

**Information for UZH students:**
Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH. Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html/

**Abstract**
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

**Objective**
Understanding of the characteristics of neuromorphic circuit elements.
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

### Recommended Subjects

*These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.*

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0121-00L</td>
<td>Communication Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>A. Wittneben</td>
</tr>
<tr>
<td>Abstract</td>
<td>Information Theory, Signal Space Analysis, Baseband Transmission, Passband Transmission, Example and Data Link Layer, MAC, Example Layer 2, Layer 3, Internet</td>
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<tr>
<td>Objective</td>
<td>Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems</td>
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<tr>
<td>Content</td>
<td>Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.</td>
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<tr>
<td>Lecture notes</td>
<td>The application of the basic methods will be extensively explained using existing and future wireless and wired systems.</td>
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<tr>
<td>Literature</td>
<td>Lecture Slides</td>
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<tr>
<td>227-0155-00L</td>
<td>Machine Learning on Microcontrollers</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Magno, L. Benini</td>
</tr>
<tr>
<td>Abstract</td>
<td>Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly “smart”. This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the “internet-of-things”, using low-power microcontrollers/processors (ARM-Cortex-M; RISC-V)</td>
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<tr>
<td>Objective</td>
<td>Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras…). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.</td>
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<tr>
<td>Content</td>
<td>The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:</td>
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<tr>
<td>Prerequisites / notice</td>
<td>- Sensors and sensor data acquisition with low power embedded systems</td>
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<tr>
<td>Prerequisites / notice</td>
<td>- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)</td>
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<tr>
<td>Prerequisites / notice</td>
<td>- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The laboratory exercised will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.</td>
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<tr>
<td>Lecture notes</td>
<td>Script and exercise sheets. Books will be suggested during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>C language programming. Basics of Digital Signal Processing. Basics of processor and computer architecture. Some exposure to machine learning concepts is also desirable</td>
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<tr>
<td>227-0157-00L</td>
<td>Semiconductor Devices: Physical Bases and Simulation</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Schenk, C. I. Roman</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.</td>
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<tr>
<td>Objective</td>
<td>The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.</td>
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</table>
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focused on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

The script (in book style) can be downloaded from: https://iis-students.ee.ethz.ch/lectures/

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the theoretical content.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

The script (in book style) can be downloaded from: https://iis-students.ee.ethz.ch/lectures/

Handouts of presented slides. No script but an accompanying textbook is recommended.


At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

The script (in book style) can be downloaded from: https://iis-students.ee.ethz.ch/lectures/

Suitable for Master Students as well as Doctoral Students.

This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture "227-0166-00L Analog Integrated Circuits" complements this lecture very well in that respect.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by copyright; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.
Simulation of Photovoltaic Devices - From Materials to Modules

Abstract
The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic energy conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules and large scale photovoltaic systems.

Objective
Get an overview over the current status of photovoltaic technology. Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to predict the performance of solar cells and modules.

Content
Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency wafer-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture)

Prerequisites / notice
Undergraduate physics, mathematics, semiconductor devices

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

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

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

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

227-0615-00L
丰硕

Solar Cells

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells.

Objective
Introduction to solar radiation, physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Content
Solar radiation characteristics, physical mechanisms for the light to electrical power conversion, properties of semiconductors for solar cells, processing and properties of conventional Si and GaAs based solar cells, technology and physics of thin film solar cells based on compound semiconductors, other solar cells including organic and dye sensitized cells, problems and new developments for power generation in space, interconnection of cells and solar module design, measurement techniques, system design of photovoltaic plants, system components such as inverters and controllers, engineering procedures with software demonstration, integration in buildings and other specific examples.

Lecture notes
Lecture reprints (in english).

Prerequisites / notice
Prerequisites: Basic knowledge of semiconductor properties.

Modeling, Characterization and Reliability of Power Semiconductors

Abstract
This lecture provides theoretical and experimental knowledge on the techniques for the characterization and numerical modeling of power semiconductors, as well on the related built-in reliability strategies.
The students shall get acquainted with the most important concepts and techniques for characterization, numerical modeling and built-in reliability of modern power semiconductor devices. This knowledge is intended to provide the future engineer with the theoretical background and tools for the design of dependable power devices and systems.

This lecture consists of a theoretical part (50%) and of laboratory exercises and demonstrations (50%). The theoretical part covers the basic techniques and procedures for characterization, modeling and built-in reliability of modern power semiconductor devices with special attention to MOS and IGBT. The starting part on technology provides an overview on the main device families and includes a review of the most relevant application-oriented aspects of the device physics, thermal management, and packaging. The second section deals with the basic experimental characterization techniques for the definition of the semiconductor material properties, electrical characteristics, safety operating area, and junction temperature of the devices. The following section introduces the basic principles for electrical, thermal, and electro-thermal simulation of power semiconductors by Technology Computer Aided Design (TCAD) and compact modeling. Finally, procedures are methods to implement efficient built-in reliability programs targeted on power semiconductors. They include failure physics, dedicated failure analysis techniques, accelerated testing, defect screening, and lifetime modeling.

During the laboratory activities, selections of the experimental techniques presented in the lecture are demonstrated on the base of realistic examples. Furthermore, schematic power devices will be simulated by the students with advanced TCAD tools and circuit simulators.

**Lecture notes**
Handouts to the lecture (approx. 250 pp.)

**Literature**
- Eichi Ohno: "Introduction to Power Electronics"
- B. Murari et al.: "Smart Power ICs"
- B. J. Baliga: "Physics Modern Power Devices"
- S. K. Ghani: "Semiconductor Power Devices"

**227-0619-00L** Charge Transport in Energy Conversion and Storage Devices

**Objective**
By the end of this course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolyzers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

**Prerequisites / notice**
Be motivated to change the world to renewable energies! Elements of calculus will be reviewed at the beginning of the course, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition.

**Literature**
- R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245

Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite. Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students. A visit to a solar cell or battery fab will be organized during the semester if the epidemiological situation permits.

**227-0653-00L** Electromagnetic Precision Measurements and Optoelectronic Devices

**Objective**
By the end of the course, the students will understand the fundamentals necessary to understand current state-of-the-art optomechanical measurement systems operating at the precision limits set by the laws of quantum mechanics.

**Prerequisites / notice**
1. Electrodynamics
2. Physics 1.2
3. Introduction to quantum mechanics

The goal of this course is to understand the fundamental limitations of measurement systems relying on electromagnetic fields.

**Literature**
- R. Huggins, Advanced Batteries, DOI:10.1007/9780387764245

Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite. Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students. A visit to a solar cell or battery fab will be organized during the semester if the epidemiological situation permits.

**227-0659-00L** Integrated Systems Seminar

**Objective**
The seminar aims at instructing graduate and PhD students in the basics of presentation techniques, i.e. "how to give a professional talk". Attendees have the possibility to become acquainted with a current topic quickly, as well as how to prepare a talk for a scientific conference, i.e. presentation techniques.

**Content**
The seminar topics are simulation of nanoelectronic processes and devices, and the optical as well as electronic simulation of optoelectronic devices as lasers, photodiodes, etc. The students learn how to find the right literature for a certain topic quickly, as well as how to prepare a talk for a scientific conference, i.e. presentation techniques.

**Lecture notes**
Presentation material

**227-0665-00L** Battery Integration Engineering

**Objective**
The students are required to have attended one of the following courses:
- 227-0664-00L Technology and Policy of Electrical Energy Storage
- 529-0440-00L Physical Electrochemistry and Electrolysis
- 529-0191-01L Renewable Energy Technologies II, Energy Storage and Conversion
- 529-0658-00L Electrochemistry (Exception for PhD students)

**Abstract**
Batteries enable sustainable mobility, renewable power integration, various power grid services, and residential energy storage. Linked with low cost PV, Li-ion batteries are positioned to shift the 19th-century centralized power grid into a 21st-century distributed one. As with battery integration, this course combines understanding of electrochemistry, heat & mass transfer, device engineering.
The learning objectives are:

- Design battery system concepts for various applications in the modern power system and sustainable mobility, with a deep focus on replacing diesel buses with electric buses combined with charging infrastructure.

- Critically assess progresses in battery integration engineering: from material science of novel battery technologies to battery system design.

- Apply “lessons learned” from the history of batteries to assess progress in battery technology.

- Apply experimental and physical concepts to develop battery models in order to predict lifetime.

- Battery systems for the modern power grid and sustainable mobility.

- Battery lifetime modeling by aging, thermal, and electric sub-models.

- Electrical architecture of battery energy storage systems.

- History and review of electrochemistry & batteries, and metrics to assess future developments in electrochemical energy stroage.

- Sustainability and life cycle analysis of battery system innovations.

Content

- Self-assembly and directed assembly of 2D and 3D structures.

- Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

Prerequisites / notice

Limited to 30 Students. Priority given to Electrical and Mechanical Engineering students.

Exception given for PhD students

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
</tr>
<tr>
<td>151-0601-00L</td>
<td>Theory of Robotics and Mechatronics</td>
<td>4</td>
<td>3G</td>
<td>P. Korba, S. Stoeter</td>
</tr>
<tr>
<td>151-0605-00L</td>
<td>Nanosystems</td>
<td>4</td>
<td>4G</td>
<td>A. Stemmer</td>
</tr>
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</table>

With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are learned. Students carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report. Limited access.

Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). They carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements for cleanliness, safety, operation of equipment and handling hazardous chemicals. Working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing, and characterization

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

### Literature
- Metamaterials
- Sensing
- Enhanced spectroscopy
- Sensing
- Metamaterials
- Surface plasmon polaritons
- Surface plasmon polariton propagation
- Localized surface plasmons

### Prerequisites / notice
Lectures and Mini-Review presentations: Thursday 10-13

Homework: Mini-Review

(compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.
C. Franck
The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They

Title
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has

U. Straumann
This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental

Multifunctional Ferroic Materials: Growth and
Charactrisation
4G
High electric fields are used in numerous technological and industrial applications such as electric power transmission and distribution, X-

M. Trassin
High voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement.

understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of

Engineering is the art of gaining technological control of high electrical field strengths and high voltages.

Prerequisites / notice
The course content and methods are designed for students with some background in management and/or economics

Objective
This course focuses, relying on a combination of lectures, case-based discussion, guest speakers, simulations and group work.

Content
This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental
decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing
things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are
small.

How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and
methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which
this course focuses, relying on a combination of lectures, case-based discussion, guest speakers, simulations and group work.

Lecture notes
Slides will be available on the Moodle page

Literature
Readings will be available on the Moodle page

Notice
The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

401-3055-64L
Algebraic Methods in Combinatorics

Abstract
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has
experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples
and focusing on basic ideas and connections to other areas.

Objective
The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the
proof techniques and to use them autonomously on related problems.

Content
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has
experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by
ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic
methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to
bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to
linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This
simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to
other areas. The topics covered in the class will include (but are not limited to):

Basic dimension arguments. Spaces of polynomials and tensor product methods, Eigenvales of graphs and their application, the
Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields,
counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey
graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice
Students are expected to have a mathematical background and should be able to write rigorous proofs.

Energy and Power Electronics
Core Subjects
These core subjects are particularly recommended for the field of "Energy and Power Electronics".

Number
227-0117-00L

Title
High Voltage Engineering

Abstract
High electric fields are used in numerous technological and industrial applications such as electric power transmission and distribution, X-
ray devices, DNA sequencers, flue gas cleaning, power electronics, lasers, particle accelerators, copying machines, .... High Voltage
Engineering is the art of gaining technological control of high electrical field strengths and high voltages.

Objective
The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They
understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of
high voltage components. They have the ability to identify of weak spots in insulation systems and to propose options for improvement.

Further, they know the different insulation systems and their dimensioning in practice.

ECTS
6

Type
W

Hours
4G

Lecturers
C. Franck, U. Straumann
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks. Moreover, the course should convey knowledge on the switching frequency related losses of power semiconductors and voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

Prerequisites / notice
Prerequisites: Introductory course on power electronics.

Lecture notes
Lecture Slides

Literature

Assessed

4G


227-0247-00L

Power Electronic Systems I

W 6 credits 4G

J. Biela, F. Krismer

Abstract
Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

Objective
Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

Content
Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses are explained. Furthermore, zero voltage switching, zero current switching, and resonant DC/DC converters are discussed in detail; the operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Lecture notes
Lecture notes and associated exercises including correct answers.

Prerequisites / notice
Prerequisites: Introductory course on power electronics.

227-0247-00L

Power Electronic Systems I

W 6 credits 4G

J. Biela, F. Krismer

Abstract
Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

Objective
Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

Content
Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses are explained. Furthermore, zero voltage switching, zero current switching, and resonant DC/DC converters are discussed in detail; the operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Lecture notes
Lecture notes and associated exercises including correct answers.

Prerequisites / notice
Prerequisites: Introductory course on power electronics.

227-0526-00L

Power System Analysis

W 6 credits 4G

G. Hug

Abstract
The goal of this course is understanding the stationary and dynamic problems in electrical power systems and the application of analysis tools in steady and dynamic states. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Objective
The goal of this course is understanding the stationary and dynamic problems in electrical power systems and the application of analysis tools in steady and dynamic states. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Content
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Lecture notes
Lecture notes.

Recommended Subjects
These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.
Content
1. Discrete-time linear systems and filters:
   state-space realizations, z-transform and spectrum,
   decimation and interpolation, digital filter design,
   stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective:
   probability, random variables, discrete-time stochastic processes;
   detection and estimation: MAP, ML, Bayesian MMSE, LMMSE;
   Wiener filter, LMS adaptive filter, Viterbi algorithm.

Lecture notes
Lecture Notes

227-0121-00L Communication Systems W 6 credits 4G A. Wittneben
Abstract
Information Theory, Signal Space Analysis, Baseband Transmission, Passband Transmission, Example of Channel, Data Link Layer, MAC, Example Layer 2, Layer 3, Internet
Objective
Introduction into the fundamentals of digital communication systems. Selected examples on the application of the fundamental principles in existing and upcoming communication systems
Content
Covered are the lower three layer of the OSI reference model: the physical, the data link, and the network layer. The basic terms of information theory are introduced. After this, we focus on the methods for the point to point communication, which may be addressed elegantly and coherently in the signal space. Methods for error detection and correction as well as protocols for the retransmission of perturbed data will be covered. Also the medium access for systems with shared medium will be discussed. Finally, algorithms for routing and flow control will be treated.

The application of the basic methods will be extensively explained using existing and future wireless and wired systems.

Lecture notes
Lecture Slides

Literature

227-0225-00L Linear System Theory W 6 credits 5G A. Iannelli
Abstract
The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

Objective
Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

Lecture notes
Available on the course Moodle platform.

Prerequisites / notice
Sufficient mathematical maturity, in particular in linear algebra, analysis.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies
- assessed
Problem-solving
- assessed

Domain D - Personal Competencies
Creative Thinking
- not assessed
Critical Thinking
- not assessed
Integrity and Work Ethics
- not assessed

227-0517-10L Fundamentals of Electric Machines W 6 credits 4G D. Bortis
Abstract
This course introduces different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective
The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

Content
- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes
Lecture notes and associated exercises including correct answers

227-0523-00L Railway Systems I W 6 credits 4G M. Meyer
Abstract
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

Objective
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1 Einführung:
  1.1 Geschichte und Struktur des Bahnsystems
  1.2 Fahrdynamik

2 Vollbahnfahrzeuge:
  2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
  2.2 Bremsen
  2.3 Traktionsantriebsysteme
  2.4 Hilfsbetriebe und Komfortanlagen
  2.5 Steuerung und Regelung

3 Infrastruktur:
  3.1 Fahrweg
  3.2 Bahnstromversorgung
  3.3 Sicherungsanlagen

4 Betrieb:
  4.1 Interoperabilität, Normen und Zulassung
  4.2 RAMS, LCC
  4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent:
Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

Taught competencies
Domain A - Subject-specific Competencies
  Concepts and Theories assessed
  Techniques and Technologies assessed
Domain B - Method-specific Competencies
  Analytical Competencies assessed
Domain D - Personal Competencies
  Critical Thinking assessed

227-0536-00L Multiphysics Simulations for Power Systems
This course is defined so and planned to be an addition to the module "227-0537-00L Technology of Electric Power System Components". However, the students who are familiar with the fundamentals of electromagnetic fields could attend only this course without its 227-0537-00L complement.

Abstract
The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations and b) performing effective simulations of primary equipment of electric power systems. The course is understood complementary to 227-0537-00L “Technology of Electric Power System Components”, but can also be taken separately.

Objective
The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL). After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

Content
1. Electromagnetic Fields and Waves: Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. Finite Element Method for electromagnetic simulations (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.,)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. Practical applications (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)

227-0567-00L Design of Power Electronic Systems
This course is defined so and planned to be an addition to the module "227-0537-00L Technology of Electric Power System Components". However, the students who are familiar with the fundamentals of electromagnetic fields could attend only this course without its 227-0537-00L complement.

Abstract
The goals of this course are a) understanding the fundamentals of the electromagnetic, thermal, mechanical, and coupled field simulations and b) performing effective simulations of primary equipment of electric power systems. The course is understood complementary to 227-0537-00L “Technology of Electric Power System Components”, but can also be taken separately.

Objective
The student should learn the fundamentals of the electromagnetic, thermal, mechanical, and coupled fields simulations necessary for modern product development and research based on virtual prototyping. She / he should also learn the theoretical background of the finite element method (FEM) and its application to low- and high-frequency electromagnetic field simulation problems. The practical exercises of the course should be done by using one of the commercially available field simulation software (Infolytica, ANSYS, and / or COMSOL). After completing the course the student should be able to properly and efficiently use the software to simulate practical design problems and to understand and interpret the obtained results.

Content
1. Electromagnetic Fields and Waves: Simulation Aspects (1 lecture, 2 hours)
   a. Short review of the governing equations
   b. Boundary conditions
   c. Initial conditions
   d. Linear and nonlinear material properties
   e. Coupled fields (electro-mechanical and electro-thermal coupling)

2. Finite Element Method for electromagnetic simulations (5 lectures and 3 exercises, 16 hours)
   a. Scalar-FEM in 2-D (electrostatic, magnetostatic, eddy-currents, etc.,)
   b. Vector-FEM in 3-D (3-D eddy-currents, wave propagation, etc.)
   c. Numerical aspects of the analysis (convergence, linear solvers, preconditioning, mesh quality, etc.)
   d. Matlab code for 2-D FEM for learning and experimenting

3. Practical applications (5 lectures and 5 exercises, 20 hours)
   a. Dielectric analysis of high-voltage equipment
   b. Nonlinear quasi-electrostatic analysis of surge arresters
   c. Eddy-currents analysis of power transformers
   d. Electromagnetic analysis of electric machines
   e. Very fast transients in gas insulated switchgears (GIS)
   f. Electromagnetic compatibility (EMC)
Abstract
Complete design process: from given specifications to a complete power electronic system; selection / design of suitable passive power components; static and dynamic properties of power semiconductors; optimized EMI filter design; heat sink optimization; additional circuitry, e.g. gate driver; system optimization.

Objective
Basic knowledge of design and optimization of a power electronic system; furthermore, lecture and exercises thoroughly discuss key subjects of power electronics that are important with respect to a practical realization, e.g. how to select suitable power components, to understand switching operations, calculation of high frequency losses, EMI filter design and realization, thermal considerations.

Content
Complete design process: from given specifications to a complete power electronic system.
Selection and / or design of suitable passive power components: specific properties, parasitic components, tolerances, high frequency losses, thermal considerations, reliability.
Static and dynamic characteristics of power semiconductors.
Optimized design of the EMI filter.
Thermal characterization of the converter, optimized heat sink design.
Additional circuitry: gate driver, measurement, control.
Converter start up: typical sequence of events, circuitry required.
Overall system optimization: identifying couplings between different components of the considered power electronic system, optimization targets and issues.

Lecture notes
Lecture notes and complementary exercises including correct answers.

Prerequisites / notice
Prerequisites: Introductory course on power electronics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>ECTS</th>
<th>Semester</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>227-0618-00L</td>
<td>Modeling, Characterization and Reliability of Power Semiconductors</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>227-0618-00L</td>
<td>M. P. M. Ciappa</td>
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<tr>
<td>227-0697-00L</td>
<td>Industrial Process Control</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>227-0697-00L</td>
<td>A. Horch, M. Mercangöz</td>
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<tr>
<td>227-0731-00L</td>
<td>Power Market I - Portfolio and Risk Management</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>227-0731-00L</td>
<td>D. Reichelt, G. A. Koeppe</td>
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</tbody>
</table>
The goal of the lecture is to get a basic understanding of international market mechanisms and their consequences for a successful enterprise. Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

Globalization of markets increases global competition and requires enterprises to continuously improve their performance to sustainably survive. Engineers substantially contribute to the success of an enterprise provided they understand and follow fundamental international market forces, economic basics and operational business management.

The first part of the course provides an overview about the development of international markets, the expected challenges and the players in the market. The second part is focusing on the economic aspects of an enterprise, their importance for the long term success and how to effectively manage an international business. Based on these fundamentals the third part of the course explains how an innovative product portfolio of a company can be derived from considering the most important external factors and which consequences in respect of product innovation, competitive product pricing, organization and business processes emerge. Each part of the course includes practical examples to demonstrate the procedure.

The lecture will be held in three blocks each of them on a Saturday (starts on September 19, 2020). Each block will focus on one of the three main topics of the course. Between the blocks the students will work on specific case studies to deepen the subject matter. About two weeks after the third block a written examination will be conducted.

These core subjects are particularly recommended for the field of "Systems and Control".

<table>
<thead>
<tr>
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<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>A. Iannelli</td>
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<td>Abstract</td>
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<td>Prerequisites / notice</td>
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<td>Taught competencies</td>
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<td>Domain A - Subject-specific Competencies</td>
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<td>Domain D - Personal Competencies</td>
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Abstract
Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing.

Objective
General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.

Content
Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries.

Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry.

Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis.

Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.

Lecture notes
Slides will be available as .PDF documents, see "Learning materials" (for registered students only)

Literature
References will be given at the end of individual lectures.

Prerequisites / notice
Exercises:

Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.

151-0563-01L Dynamic Programming and Optimal Control W 4 credits 2V+1U R. D’Andrea

Abstract
Introduction to Dynamic Programming and Optimal Control.

Objective
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

Content
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

Literature

Prerequisites / notice
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

Recommended Subjects
These courses are recommended, but you are free to choose courses from any other special field. Please consult your tutor.

Number Title Type ECTS Hours Lecturers
227-0102-00L Discrete Event Systems W 6 credits 4G R. Jacob, L. Vanbever, R. Wattenhofer

Abstract
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.

Objective
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content
1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes
Available
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Objective

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes

Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice

Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0526-00L Power System Analysis

Abstract

The goal of this course is understanding the stationary and dynamic problems in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Objective

The goal of this course is understanding the stationary and dynamic problems in electrical power systems and the application of analysis tools in steady and dynamic states.

Content

The course includes the development of stationary models of the electrical network, their mathematical representation, and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

Lecture notes

Lecture notes, Lecture notes.

227-0531-00L Control of Power-Electronics-Dominated Power Systems

Abstract

The penetration of renewable energy, storage systems, EVs and DC systems in combination with the phase-out of synchronous generation, is leading to a power electronics (PE)-dominated power system, implying relevant challenges at network operation and control levels. The course covers modeling, analysis and control design aspects for future PE-dominated networks.

Objective

The course objectives are:
- Understand the fundamentals of PE-dominated power systems
- Learn how to model, analyze and control grid-connected power converters
- Apply the acquired modelling, analysis and control design techniques to real application power converters
- Acquire techniques to assess the impact of PE devices within the power network.

Content

The course covers the following topics:
- Future PE-dominated power systems. Main applications and challenges.
- Voltage source converter review. Different structures 2L, 3L, Modular Multilevel Converters (MMC).
- 2L/3L VSCs: Main control blocks. Usual transformations.
- Voltage source converter review. Concept definition and main structures. Different control options.
- MMC Applications. Control design and implementation.
- PE-dominated system stability and interaction analysis. Linearization of converter and power system dynamics. Eigenvalue analysis.
- Participation factors.

Lecture notes

Lecture notes will be provided in class.

Literature

Specific literature will be provided with the lecture notes.
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**System Identification**


**Adaptability and Flexibility**

**Concepts and Theories**

**Techniques and Technologies**

**Analytical Competencies**

**Media and Digital Technologies**

**Problem-solving**

**Cooperation and Teamwork**

**Leadership and Responsibility**

**Adaptability and Flexibility**

**Critical Thinking**

**Self-direction and Self-management**

---

**System Identification**

W 4 credits 2V+1U R. Smith

Abstract

Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content

Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.

Literature


Additional papers will be available via the course Moodle.

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**Cell and Molecular Biology for Engineers I**

W 3 credits 2G C. Frei

Abstract

This course is part I of a two-semester course.

Objective

The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Content

Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication. These written documents will be graded and count as 40% for the final grade.

Literature


Additional papers will be available via the course Moodle.

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**Nonlinear Dynamics and Chaos I**

W 4 credits 2V+2U G. Haller

Abstract

Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective

This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

---

Content

(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.

(2) Near equilibrium dynamics: Linear and Lyapunov stability

(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations

(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.

(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes

The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice

- Prerequisites: Analysis, linear algebra and a basic course in differential equations.

- Exam: two-hour written exam in English.

- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecturer(s)</th>
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<tbody>
<tr>
<td>151-0573-00L</td>
<td>System Modeling</td>
<td>W 4</td>
<td>L. Guzzella</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to system modeling for control. Generic modeling approaches based on first principles, Lagrangian formalism, energy approaches and experimental data. Model parametrization and parameter estimation. Basic analysis of linear and nonlinear systems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.</td>
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</tr>
<tr>
<td>Content</td>
<td>This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronic, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.</td>
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<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0601-00L</td>
<td>Theory of Robotics and Mechatronics</td>
<td>W 4</td>
<td>P. Korba, S. Stoeter</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.</td>
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<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0563-01L</td>
<td>Dynamic Programming and Optimal Control</td>
<td>W 4</td>
<td>R. D’Andrea</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Dynamic Programming and Optimal Control.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Covers the fundamental concepts of Dynamic Programming &amp; Optimal Control.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.</td>
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</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>W 3</td>
<td>R. Rienier, O. Lambercy</td>
</tr>
<tr>
<td>Abstract</td>
<td>Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.</td>
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</tr>
</tbody>
</table>

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature
Introductory Books:

Selected Journal Articles and Web Links:

Prerequisites / notice
VideoTact, ForeThought Development, LLC. http://my.execpc.com/?dwysocki/videotac.html

Target Group:
- Students of higher semesters and PhD students of
  - D-MAVT, D-ITET, D-INFK, D-HEST
  - Biomedical Engineering, Robotics, Systems and Control
  - Medical Faculty, University of Zurich
  - Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

401-0647-00L Introduction to Mathematical Optimization W 5 credits 2V+1U D. Adjiashvili
**Abstract**

Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.

**Objective**

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

**Content**

Topics covered in this course include:

- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

**Literature**

Information about relevant literature will be given in the lecture.

**Prerequisites / notice**

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

**401-3901-00L**

**Linear & Combinatorial Optimization**

- R. Zenklusen

**Abstract**

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**

Key topics include:

- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**


**Prerequisites / notice**

Solid background in linear algebra.

**636-0007-00L**

**Computational Systems Biology**

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modelling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

**Abstract**

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

**Objective**

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

**Lecture notes**

http://www.csb.ethz.ch/education/lectures.html

**Literature**


The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk’s conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Prerequisites / notice

Students are expected to have a mathematical background and should be able to write rigorous proofs.

### Signal Processing and Machine Learning

#### Core Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td>227-0427-00L</td>
<td>Signal Analysis, Models, and Machine Learning</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
</tbody>
</table>

#### Objective

- Students master the basic mathematical concepts and algorithms of estimation and machine learning.

#### Content

- Review of probability theory;
- Basics of statistical estimation;
- Least squares and linear learning;
- Hilbert spaces;
- Gaussian random variables;
- Singular-value decomposition;
- Kernel methods, neural networks, and more.

#### Lecture notes

Lecture notes will be handed out as the course progresses.

#### Prerequisites / notice

- This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

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Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience

Lecturers

ECTS


Objective

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes

Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice

Prerequisites: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, J. Cotrini Jimenez

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals: What is data?
- Bayesian Learning
- Computational learning theory
- Supervised learning: Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks
- Unsupervised learning: Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamic Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Recommended Subjects

Number Title Type ECTS Hours Lecturers

227-0101-00L Discrete-Time and Statistical Signal Processing W 6 credits 4G H.-A. Loeliger
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMS filtering, LMS algorithm, Viterbi algorithm.

**Objective**

The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMS filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

**Content**

1. Discrete-time linear systems and filters: state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

**Lecture notes**

Lecture Notes

**227-0116-00L**

**VLSI 1: HDL based design for FPGAs**

**Abstract**

This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

**Objective**

Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

**Content**

This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:

- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

**Lecture notes**

Textbook and all further documents in English.

**Literature**


**Prerequisites / notice**

- Basics of digital circuits.

**Examination:**

In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:

https://iis-students.ee.ethz.ch/lectures/vlsi-i/

**227-0155-00L**

**Machine Learning on Microcontrollers**

**Abstract**

Registration in this class requires the permission of the instructors. Class size will be limited to 25. Preference is given to students in the MSc EEIT.

Machine Learning (ML) and artificial intelligence are pervading the digital society. Today, even low power embedded systems are incorporating ML, becoming increasingly "smart". This lecture gives an overview of ML methods and algorithms to process and extract useful near-sensor information in end-nodes of the "internet-of-things", using low-power microcontrollers/processors (ARM-Cortex-M, RISC-V).

**Objective**

Learn how to Process data from sensors and how to extract useful information with low power microprocessors using ML techniques. We will analyze data coming from real low-power sensors (accelerometers, microphones, ExG bio-signals, cameras...). The main objective is to study in details how Machine Learning algorithms can be adapted to the performance constraints and limited resources of low-power microcontrollers.
The final goal of the course is a deep understanding of machine learning and its practical implementation on single- and multi-core microcontrollers, coupled with performance and energy efficiency analysis and optimization. The main topics of the course include:

- Sensors and sensor data acquisition with low power embedded systems
- Machine Learning: Overview of supervised and unsupervised learning and in particular supervised learning (Bayes Decision Theory, Decision Trees, Random Forests, kNN-Methods, Support Vector Machines, Convolutional Networks and Deep Learning)
- Low-power embedded systems and their architecture. Low Power microcontrollers (ARM-Cortex M) and RISC-V-based Parallel Ultra Low Power (PULP) systems-on-chip.
- Low power smart sensor system design: hardware-software tradeoffs, analysis, and optimization. Implementation and performance evaluation of ML in battery-operated embedded systems.

The laboratory exercised will show how to address concrete design problems, like motion, gesture recognition, emotion detection, image and sound classification, using real sensors data and real MCU boards.

Presentations from Ph.D. students and the visit to the Digital Circuits and Systems Group will introduce current research topics and international research projects.

### 227-0225-00L Linear System Theory

**Objective**: Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

**Content**:
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

**Prerequisites / notice**
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed
- Domain D - Personal Competencies
  - Creative Thinking: not assessed
  - Critical Thinking: not assessed
  - Integrity and Work Ethics: not assessed

**Lecture notes**
- Script and exercise sheets. Books will be suggested during the course.

**227-0417-00L Information Theory I**

This course covers the basic concepts of information theory and its communication theory. Topics covered include the entropy rate of a source and mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity. The main goal of this lecture is to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.

**Objective**: Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.

**Content**:
- Proof techniques and practices.
- Linear spaces, normed linear spaces and Hilbert spaces.
- Ordinary differential equations, existence and uniqueness of solutions.
- Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
- Controllability and observability, duality. Time invariant systems treated as a special case.
- Stability and stabilization, observers, state and output feedback, separation principle.

**Prerequisites / notice**
- Sufficient mathematical maturity, in particular in linear algebra, analysis.

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed
- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Problem-solving: assessed
- Domain D - Personal Competencies
  - Creative Thinking: not assessed
  - Critical Thinking: not assessed
  - Integrity and Work Ethics: not assessed

**Lecture notes**
- Available on the course Moodle platform.

**227-0421-00L Deep Learning in Artificial and Biomedical Neuronal Networks**

**Abstract**: Deep-Learning (DL) is a brain-inspired weak form of AI that allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

**Objective**: The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neurosciences papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g., digit classification) tasks in a supervised manner.

**Content**
- Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world.

However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al. 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.
### 227-0477-00L Acoustics I

**Objective**
Understanding of the basic acoustic concepts and methods. Ability to understand the technical and scientific literature. Confidence in the use of measuring instruments.

**Content**
Fundamentals of acoustics, measurement and analysis of acoustical events, anatomy and properties of the ear, outdoor sound propagation, absorption and transmission of sound, room acoustics of large and small enclosures, architectural acoustics, noise and noise control, calculation of sound fields.

**Lecture notes**
The lecture slides will be provided as a PDF after each lecture.

**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Self-direction and Self-management | not assessed |

### 263-5210-00L Probabilistic Artificial Intelligence

**Objective**
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics.

**Content**
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

### 263-5255-00L Foundations of Reinforcement Learning

**Objective**
By the end of the course, students will be able to
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Generalize or discover "new" applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

**Content**
Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

**Lecture notes**
Lecture notes will be posted on Moodle.

**Literature**
Dynamic Programming and Optimal Control, Vol I & II, Dimitri Bertsekas
Algorithms for Reinforcement Learning, Csaba Czepevsévaří.

**Prerequisites / notice**
Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

### 401-3901-00L Linear & Combinatorial Optimization

**Objective**
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Adaptability and Flexibility

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure $A$ one maps its elements to vectors in a linear space, and shows that the set $A$ is mapped to linearly independent vectors. It then follows that the cardinality of $A$ is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments. Spaces of polynomials and tensor product methods.
- Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Subjects of General Interest

These courses are suitable for several special fields. Please consult your tutor.
The handout is available in German and English.

Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a scientific text.

Internship in Industry

Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality

The goal of the lecture is to provide a deeper knowledge of today's VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

Didactical concept:
The course consists of lectures and exercises.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies
Media and Digital Technologies

Domain C - Social Competencies
Communication
Cooperation and Teamwork

Domain D - Personal Competencies
Creative Thinking
Critical Thinking

Internship in Industry

The main objective of the 12-week internship is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Semester Projects

How to Write Scientific Texts

The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be thought on two afternoons. Some exercises will be built into the lecture.

Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).

* Topic 2: Power Point Presentations.

* Topic 3: Citation Rules and Software.

* Topic 4: Guidelines for Research Integrity.

ETH "Citation Etiquette", see www.plagiate.ethz.ch.


Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.
Abstract
Semester projects are designed to train the students for independent scientific work. A project uses the student's technical and social skills acquired during the master's program. The semester project comprises 280 hours of work and is supervised by a professor.

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1572-02L</td>
<td>Semester Project (Nr 2)</td>
<td>W</td>
<td>12</td>
<td>20A</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
The second semester project is compulsory for students enrolled in the MSc EEIT under the 2008 regulations, it is optional for students enrolled under the 2018 regulations.

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

GESS Science in Perspective

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ITET

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Abstract
The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training.

Objective
Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content
- Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).
- Topic 2: Power Point Presentations.
- Topic 3: Citation Rules and Citation Software.
- Topic 4: Guidelines for Research Integrity.

Literature
ETH “Citation Etiquette”, see www.plagiate.ethz.ch.

Prerequisites / notice
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1501-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>68D</td>
<td></td>
</tr>
</tbody>
</table>

Note: the conditions above are not applicable to incoming exchange students.

Registration in mystudies required!
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html.

Abstract
The Master Program finishes with a 6-months Master Thesis which is directed by a Professor of the Department or a Professor of another Department who is associated with the D-ITET. Students gain the ability to conduct independent scientific research on a specific research problem.

Prerequisites / notice
Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

Generally Accessible Seminars and Colloquia
Seminar in Systems and Control

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of
K. P. Prüssmann

Abstract

Selected topics of the current research activities at the IEF and closely related institutions are discussed. Have an overview on the research activities of the IEF institute.

Research Topics in Biomedical Engineering

Does not take place this semester.

K. P. Prüssmann, S. Kozerke, M. Stampanoni, K. Stephan, J. Vörös

Abstract

Current topics in Biomedical Engineering presented by speakers from academia and industry. Getting insight into actual areas and problems of Biomedical Engineering an Health Care.

Seminar on Biomedical Magnetic Resonance

Z 0 credits 1S

K. P. Prüssmann, S. Kozerke, M. Weiger Senften

Abstract

Current developments and problems of magnetic resonance imaging (MRI) Getting insight into advanced topics in magnetic resonance imaging

Foundations of Data Science Seminar

Z 0 credits

P. L. Bühlmann, A. Bandeira, H. Bölcskei, F. Yang

Abstract

Research colloquium

Course Units for Additional Admission Requirements

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

Discrete-Time and Statistical Signal Processing

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

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

The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter.

1. Discrete-time linear systems and filters:
state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.

2. The discrete Fourier transform and its use for digital filtering.

3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

Control Systems

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

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

Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.


Analog Integrated Circuits

This course provides a foundation in analog integrated circuit design based on CMOS technologies. Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems. The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content
- Review of bipolar and MOS devices and their small-signal equivalent circuit models;
- Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc;
- Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps;
- Stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

Lecture notes
Handouts of slides. No script but an accompanying textbook is recommended.

Literature

High Voltage Engineering

The students know the fundamental phenomena and principles connected with the occurrence of extensive electric field strengths. This knowledge is applied to the dimensioning of high-voltage equipment. Methods of computer-modeling in use today are presented and applied within a workshop in the framework of the exercises.

Content
- discussion of the field equations relevant for high voltage engineering.
- analytical and numerical solutions/solving of these equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations
- introduction to kinetic theory of gases
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components
- exercise to learn on computer-modeling in high voltage engineering

Lecture notes
Lecture Slides

Literature

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Energy Science and Technology Master

### Core Courses

At least two core courses must be passed in each area.
All students must participate in the course offered in the area "Interdisciplinary Energy Management"

### Electrical Power Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0122-00L</td>
<td>Introduction to Electric Power Transmission: System &amp; Technology</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>C. Franck, G. Hug</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to theory and technology of electric power transmission systems.

**Objective**
At the end of this course, the student will be able to: describe the structure of electric power systems, name the most important components and describe what they are needed for, apply models for transformers and overhead power lines, explain the technology of transformers and lines, calculate stationary power flows and other basic parameters in simple power systems.

**Content**
Structure of electric power systems, transformer and power line models, analysis of and power flow calculation in basic systems, technology and principle of electric power systems.

**Lecture notes**
Lecture script in English, exercises and sample solutions.

### Energy Flows and Processes

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1635-00L</td>
<td>Electric Circuits</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Zima, D. Shchetinin</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to analysis methods and network theorems to describe operation of electric circuits. Theoretical foundations are essential for the analysis of the electric power transmission and distribution grids as well as many modern technological devices – consumer electronics, control systems, computers and communications.

**Objective**
At the end of this course, the student will be able to: understand variables in electric circuits, evaluate possible approaches and analyse simple electric circuits with RLC elements, apply circuit theorems to simple meshed circuits, analyze AC circuits in a steady state and understand the connection of the explained principles to the modelling of the 3-phase electric power systems.

**Content**
Course will introduce electric circuits variables, circuit elements (resistive, inductive, capacitive), resistive circuits and theorems (Kirchhoffs' laws, Norton and Thvenin equivalents), nodal and mesh analysis, superposition principle; it will continue by discussing the complete response circuits (RLC), sinusoidal analysis – ac steady state (complex power, reactive, active power) and conclude with the introduction to 3-phase analysis; Mathematical foundations of the circuit analysis, such as matrix operations and complex numbers will be briefly reviewed. This course is targeting students who have no prior background in electrical engineering.

**Literature**
Lecture notes and exercise slides will be distributed after each lecture via moodle platform; additional materials to be accessed online (wileyplus)

**Prerequisites / notice**
This course is intended for students outside of D-ITET. No prior course in electrical engineering is required.
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and illustrate how these affect the economy as a whole. (4) Students can identify market failures such as externalities related to market activities and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:
- Supply and demand
- Consumer demand: neoclassical and behavourial perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

Lecture notes
Lecture notes, exercises and reference material can be downloaded from Moodle.

Literature


Complementary:

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

Interdisciplinary Energy Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only for Energy Science and Technology MSc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract
This course will allow the students to get an interdisciplinary overview of the "Energy" topic. It will explore the challenges to build a sustainable energy system for the future. This will be done through the means of case studies that the students have to work on. These case studies will be provided by industry partners.

Objective
The students will understand the different aspects involved in designing solutions for a sustainable future energy system. They will have experience in collaborating in interdisciplinary teams. They will have an understanding on how industry is approaching new solutions.

Lecture notes
Descriptions of case studies.
Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Domain D - Personal Competencies

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1650-10L</td>
<td>Internship in Industry</td>
<td>O</td>
<td>12</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Abstract
The main objective of the 12-week internship is to expose master's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Abstract
The 4 hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be thought on two afternoons. Some exercises will be built into the lecture.

Objective
Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content
* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).
  * Topic 2: Power Point Presentations.
  * Topic 3: Citation Rules and Citation Software.
  * Topic 4: Guidelines for Research Integrity.

Literature
ETH "Citation Etiquette", see www.plagiate.ethz.ch.

Prerequisites / notice
Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

Electives

These courses are particularly recommended, other ETH-courses from the field of Energy Science and Technology at large may be chosen in accordance with your tutor.

Electrical Power Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0113-00L</td>
<td>Power Electronics</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. W. Kolar</td>
</tr>
</tbody>
</table>

Abstract
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis, procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Objective
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis, procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time; single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; isolated DCDC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with singe triangular carrier and individual carrier signals of the phases.

The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement. Further, they know the different insulation systems and their dimensioning in practice.

- discussion of the field equations relevant for high voltage engineering.
- analytical and numerical solutions/solving of this equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations
- introduction to kinetic gas theory
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components

Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

Lecture notes
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Literature

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain A - Method-specific Competencies | Techniques and Technologies | not assessed |
| Domain B - Analytical Competencies | Decision-making | not assessed |
| Domain B - Media and Digital Technologies | Problem-solving | assessed |
| Domain B - Project Management | not assessed |
| Domain C - Communication | not assessed |
| Domain C - Cooperation and Teamwork | not assessed |
| Domain C - Leadership and Responsibility | not assessed |
| Domain C - Self-presentation and Social Influence | not assessed |
| Domain C - Sensitivity to Diversity | not assessed |
| Domain C - Negotiation | not assessed |
| Domain D - Adaptability and Flexibility | not assessed |
| Domain D - Creative Thinking | not assessed |
| Domain D - Critical Thinking | not assessed |
| Domain D - Integrity and Work Ethics | not assessed |
| Domain D - Self-awareness and Self-reflection | not assessed |
| Domain D - Self-direction and Self-management | not assessed |

High Voltage Engineering

High electric fields are used in numerous technological and industrial applications such as electric power transmission and distribution, X-ray devices, DNA sequencers, flue gas cleaning, power electronics, lasers, particle accelerators, copying machines, .... High Voltage Engineering is the art of gaining technological control of high electrical field strengths and high voltages.

The students know the fundamental phenomena and principles associated with the occurrence of high electric field strengths. They understand the different mechanisms leading to the failure of insulation systems and are able to apply failure criteria on the dimensioning of high voltage components. They have the ability to identify weak spots in insulation systems and to propose options for improvement. Further, they know the different insulation systems and their dimensioning in practice.

- discussion of the field equations relevant for high voltage engineering.
- analytical and numerical solutions/solving of this equations, as well as the derivation of the important equivalent circuits for the description of the fields and losses in insulations
- introduction to kinetic gas theory
- mechanisms of the breakdown in gaseous, liquid and solid insulations, as well as insulation systems
- methods for the mathematical determination of the electric withstand of gaseous, liquid and solid insulations
- application of the expertise on high voltage components
- excursions to manufacturers of high voltage components

Lecture Slides

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain A - Method-specific Competencies | Techniques and Technologies | assessed |
| Domain B - Analytical Competencies | Decision-making | not assessed |
| Domain B - Media and Digital Technologies | Problem-solving | not assessed |
| Domain B - Project Management | not assessed |
| Domain C - Communication | not assessed |
| Domain C - Cooperation and Teamwork | not assessed |
| Domain C - Leadership and Responsibility | not assessed |
| Domain C - Self-presentation and Social Influence | not assessed |
| Domain C - Sensitivity to Diversity | not assessed |
| Domain C - Negotiation | not assessed |
| Domain D - Adaptability and Flexibility | not assessed |
| Domain D - Creative Thinking | not assessed |
| Domain D - Critical Thinking | not assessed |
| Domain D - Integrity and Work Ethics | not assessed |
| Domain D - Self-awareness and Self-reflection | not assessed |
| Domain D - Self-direction and Self-management | not assessed |

Power Electronic Systems I

Power Electronic Systems I

Lecture Slides

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain A - Analytical Competencies | Decision-making | not assessed |
| Domain A - Media and Digital Technologies | Problem-solving | not assessed |
| Domain A - Project Management | not assessed |
| Domain B - Communication | not assessed |
| Domain B - Cooperation and Teamwork | not assessed |
| Domain B - Leadership and Responsibility | not assessed |
| Domain B - Self-presentation and Social Influence | not assessed |
| Domain B - Sensitivity to Diversity | not assessed |
| Domain B - Negotiation | not assessed |
| Domain C - Adaptability and Flexibility | not assessed |
| Domain C - Creative Thinking | not assessed |
| Domain C - Critical Thinking | not assessed |
| Domain C - Integrity and Work Ethics | not assessed |
| Domain C - Self-awareness and Self-reflection | not assessed |
| Domain C - Self-direction and Self-management | not assessed |
Abstract
Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications.

Objective
Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and inductive power components and introduce the concept of space vector calculus which provides a basis for the comprehensive discussion of three-phase PWM converters systems in the lecture Power Electronic Systems II.

Content
Basics of the switching behavior and gate drive circuits of power semiconductor devices and auxiliary circuits for minimizing the switching losses are explained. Furthermore, zero voltage switching, zero current switching, and resonant DC/DC converters are discussed in detail; the operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.

Lecture notes
Lecture notes and associated exercises including correct answers.

Prerequisites / notice
Prerequisites: Introductory course on power electronics.

227-0311-00L Qubits, Electrons, Photons W 6 credits 3V+2U T. Zambelli

Abstract
In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).

Objective
Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.

Starting from the axioms of quantum mechanics, we will derive the fascinating theory describing spin and qubits, electron transitions and transfer, photons and LASER: quantum mechanics is different because it mocks our daily Euclidean intuition!

In this way, students will work out a robust quantum mechanics (theoretical!) basis which will help them in their advanced studies of the following masters: EEIT (batteries), Biomedical Engineering (NMR, bioelectronics), Quantum Engineering, Micro- and Nanosystems.

Content
• Lagrangian and Hamiltonian: Symmetries and Poisson Brackets
• Postulates of QM: Hilbert Spaces and Operators
• Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator
• Spin: Qubits, Bloch Equations, and NMR
• Entanglement
• Symmetries and Corresponding Operators
• Schrödinger’s Wave Mechanics: Electrons in a Periodic Potential and Energy Bands
• Harmonic Oscillator: Creation and Annihilation Operators
• Identical Particles: Bosons and Fermions
• Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER
• Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener

Lecture notes
No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive!

!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature

Supplementary material will be uploaded in Moodle.

Prerequisites / notice
The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET “Physics II”.

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in moodle!
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td>Decision-making</td>
<td>assessed</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td>Project Management</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Customer Orientation</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<tr>
<td></td>
<td>Negotiation</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
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#### 227-0523-00L Railway Systems I

<table>
<thead>
<tr>
<th>Abstract</th>
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<tbody>
<tr>
<td>Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:</td>
</tr>
<tr>
<td>- Transportation tasks and vehicle types</td>
</tr>
<tr>
<td>- Running dynamics</td>
</tr>
<tr>
<td>- Mechanical part of rail vehicles</td>
</tr>
<tr>
<td>- Brakes</td>
</tr>
<tr>
<td>- Traction chain and auxiliary supply</td>
</tr>
<tr>
<td>- Railway power supply</td>
</tr>
<tr>
<td>- Signalling systems</td>
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<tr>
<td>- Standards</td>
</tr>
<tr>
<td>- Availability and safety</td>
</tr>
<tr>
<td>- Traffic control and maintenance</td>
</tr>
<tr>
<td>- Overview of the technical characteristics of railway systems</td>
</tr>
<tr>
<td>- Know-how about the design and construction principles of rail vehicles</td>
</tr>
<tr>
<td>- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)</td>
</tr>
<tr>
<td>- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries</td>
</tr>
<tr>
<td>- Insight into the activities of the railway vehicle industry and railway operators in Switzerland</td>
</tr>
<tr>
<td>- Motivation of young engineers to start a career in the railway industry or with railway operators</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective</th>
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</thead>
<tbody>
<tr>
<td>- EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale</td>
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</table>

<table>
<thead>
<tr>
<th>Content</th>
</tr>
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<tbody>
<tr>
<td>1 Einführung:</td>
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<tr>
<td>1.1 Geschichte und Struktur des Bahnsystems</td>
</tr>
<tr>
<td>1.2 Fahrdynamik</td>
</tr>
<tr>
<td>2 Vollbahnfahrzeuge:</td>
</tr>
<tr>
<td>2.3 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion</td>
</tr>
<tr>
<td>2.2 Bremse</td>
</tr>
<tr>
<td>2.3 Traktionsantriebssysteme</td>
</tr>
<tr>
<td>2.4 Hilfsbetriebe und Komfortanlagen</td>
</tr>
<tr>
<td>2.5 Steuerung und Regelung</td>
</tr>
<tr>
<td>3 Infrastruktur:</td>
</tr>
<tr>
<td>3.1 Fahrweg</td>
</tr>
<tr>
<td>3.2 Bahnstromversorgung</td>
</tr>
<tr>
<td>3.3 Sicherungsanlagen</td>
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<tr>
<td>4 Betrieb:</td>
</tr>
<tr>
<td>4.1 Interoperabilität, Normen und Zulassung</td>
</tr>
<tr>
<td>4.2 RAMS, LCC</td>
</tr>
<tr>
<td>4.3 Anwendungsbeispiele</td>
</tr>
</tbody>
</table>

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

**Geplante Exkursionen:**
- Betriebszentrale SBB, Zürich Flughafen
- Reparatur und Unterhalt, SBB Zürich Altstetten
- Fahrzeugfertigung, Stadler Bussnang

**Lecture notes**
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

**Prerequisites / notice**

**Dozent:**
Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahninfrastruktur.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
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</tbody>
</table>

#### 227-0526-00L Power System Analysis

<table>
<thead>
<tr>
<th>W 6 credits 4G G. Hug</th>
</tr>
</thead>
</table>

Abstract
The goal of this course is understanding the stationary and dynamic problems in electrical power systems. The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power networks.

Objective
The objective of this course is understanding the stationary and dynamic problems in electrical power systems and the application of analysis tools in steady and dynamic states.

Content
The course includes the understanding of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

Lecture notes
Lecture notes.
Abstract
Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.

Objective

Content
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX

2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions

3. Portfolio and Risk Management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (m2m, VaR, EPE, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2

2.8. Risk Management 3 (enterprise wide)

4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

Lecture notes
Handouts of the lecture
Course Moodle: https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636

227-0615-00L Simulation of Photovoltaic Devices - From Materials to Modules

Abstract
The lecture provides an introduction to the theoretical foundations and numerical approaches for the simulation of photovoltaic energy conversion, from the microscopic description of component materials to macroscopic continuum modelling of solar cells and network simulation or effective models for performance prediction of entire solar modules and large scale photovoltaic systems.

Objective
Get an overview over the current status of photovoltaic technology, Understand the physics of photovoltaic energy conversion and solar cell device operation. Know how to obtain and assess by simulation the key material properties and device parameters. Be able to use standard device simulation tools to predict the performance of solar cells and modules.

Content
Photovoltaic technology: history and overview; The solar spectrum; Thermodynamics of solar energy conversion; Detailed balance models and efficiency limit; Microscopic rates of charge carrier generation and recombination; Optical simulation of solar cells; Models for charge transport in semiconductor devices; High-efficiency water-based (silicon) photovoltaics; Thin film photovoltaics based on disordered materials (amorphous silicon, organic PV); High-efficiency thin film photovoltaics (CIGS, CdTe, metal-halide perovskites); PV beyond the single junction detailed balance (Shockley-Queisser) limit; Simulation of photovoltaic modules; Energy yield and performance modelling for PV systems; Quantum simulation of nanostructure-based solar cell devices (bonus lecture)

Prerequisites / notice
Undergraduate physics, mathematics, semiconductor devices

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

Domain B - Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - not assessed
- Media and Digital Technologies
  - not assessed
- Problem-solving
  - assessed
- Project Management
  - not assessed

Domain C - Social Competencies
- Communication
  - not assessed
- Cooperation and Teamwork
  - not assessed
- Customer Orientation
  - not assessed
- Leadership and Responsibility
  - not assessed
- Self-presentation and Social Influence
  - not assessed
- Sensitivity to Diversity
  - not assessed
- Negotiation
  - not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility
  - not assessed
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - not assessed
- Self-awareness and Self-reflection
  - not assessed
- Self-direction and Self-management
  - not assessed

227-0617-00L Solar Cells

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells.

Objective
Introduction to solar radiation, physics, technology, characteristics and applications of photovoltaic solar cells and systems.
Energy Flows and Processes

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>151-0123-00L</td>
<td>Experimental Methods for Engineers</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>T. Rössgen, B. Schuemans, M. Tibbitt</td>
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<tr>
<td>151-0163-00L</td>
<td>Nuclear Energy Conversion</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. Manera</td>
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<td>151-0185-00L</td>
<td>Radiation Heat Transfer</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. Steinfield, P. Pozivil</td>
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<tr>
<td>151-0185-00L</td>
<td>Renewable Energy Technologies</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>A. Steinfeld, E. I. M. Casati</td>
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</tbody>
</table>

Abstract

The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial in-class introduction, laboratory exercises from different application areas (especially in thermofluidics and process engineering) are attended by students in small groups.

Objective

Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic applications. Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization. Students get an overview on energy conversion in nuclear power plants, on construction and function of the most important types of nuclear reactors with special emphasis to light water reactors. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

Content

In-class introduction to representative measurement techniques in the research areas of the participating institutes (fluid dynamics, energy technology, process engineering), student participation in 8-10 laboratory experiments (study groups of 3-5 students, dependent on the number of course participants and available experiments).

Literature


Prerequisites / notice

Basic understanding in the following areas:
- fluid mechanics, thermodynamics, heat and mass transfer
- electrical engineering / electronics
- numerical data analysis and processing (e.g. using MATLAB)

Abstract

Physical fundamentals of the fission reaction and the sustainable chain reaction, thermal design, construction, function and operation of nuclear reactors, power plants, light water reactors and other reactor types, conversion and breeding.

Content

Nuclear physics of fission and chain reaction. Thermodynamics of nuclear reactors. Design of the reactor core. Introduction into the dynamic behaviour of nuclear reactors. Overview on types of nuclear reactors, difference between thermal reactors and fast breeders. Construction and operation of nuclear power plants with pressurized and boiling water reactors, role and function of the most important safety systems, special features of the energy conversion. Development tendencies of reactor technology.

Literature


R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier
This lecture aims at introducing the students to the working principles and efficiency optimization methods for Internal Combustion (IC) Engine Systems. This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations. Reaction kinetics, fuel oxidation mechanisms, premixed and diffusion laminar flames, two-phase-flows, turbulence and turbulent wind energy. N. Chokani

The students should become familiar with the fundamentals and with application examples of chemically reactive processes in energy system, modelling and optimization of IC engines. Y. M. Wright


The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics. C. Onder


The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics. J. Warnatz, U. Maas, R.W. Dibble, "Combustion:Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation", Springer-Verlag, 1997.
Abstract
Introduction to current and future engine systems and their control systems.

Objective
Introduction to methods of control and optimization of dynamic systems. Application to real engines. Understand the structure and behavior of drive train systems and their quantitative descriptions.

Content
Physical description and mathematical models of components and subsystems (mixture formation, load control, supercharging, emissions, drive train components, etc.). Case studies of model-based optimal design and control of engine systems with the goal of minimizing fuel consumption and emissions.

Lecture notes
Introduction to Modeling and Control of Internal Combustion Engine Systems
Guzzella Lino, Onder Christopher H.
ISBN: 978-3-642-10774-0

Prerequisites / notice
Combined homework and testbench exercise (air-to-fuel-ratio control or idle-speed control) in groups

<table>
<thead>
<tr>
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<th>Type</th>
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<tr>
<td>151-0569-00L</td>
<td>Vehicle Propulsion Systems</td>
<td>W</td>
<td>4</td>
<td>C. Onder, P. Elbert</td>
</tr>
</tbody>
</table>

Abstract
Introduction to current and future propulsion systems and the electronic control of their longitudinal behavior.

Objective
Introduction to methods of system optimization and controller design for vehicles. Understanding the structure and working principles of conventional and new propulsion systems. Quantitative descriptions of propulsion systems.

Content
Understanding of physical phenomena and mathematical models of components and subsystems (manual, automatic and continuously variable transmissions, energy storage systems, electric drive trains, batteries, hybrid systems, fuel cells, road/wheel interaction, automatic braking systems, etc.).

Presentation of mathematical methods, CAE tools and case studies for the model-based design and control of propulsion systems with the goal of minimizing fuel consumption and emissions.

Lecture notes
Vehicle Propulsion Systems -- Introduction to Modeling and Optimization
Guzzella Lino, Sciarretta Antonio
ISBN: 978-3-642-35912-5

Prerequisites / notice
Lectures of Prof. Dr. Ch. Onder and Dr. Ph. Elbert are also possible to be held in German.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0613-01L</td>
<td>Process Simulation and Flowsheeting</td>
<td>W</td>
<td>6</td>
<td>G. Guillén Gosálvez</td>
</tr>
</tbody>
</table>

Abstract
This course encompasses the theoretical principles of chemical process simulation and optimization, as well as its practical application in process analysis. The techniques for simulating stationary and dynamic processes are presented, and illustrated with case studies. Commercial software packages (Aspen) are introduced for solving process flowsheeting and optimization problems.

Objective
This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization. Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the set of relevant mathematical relations, which describe the process behavior.
- Mathematical reasoning and computational skills: the familiarization with mathematical algorithms and computational tools is essential to be capable of achieving rapid and reliable solutions to simulation and optimization problems. Hence, students will learn the mathematical principles necessary for process simulation and optimization, as well as the structure and application of process simulation software. Thus, they will be able to develop criteria to correctly use commercial software packages and critically evaluate their results.
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.

Content
Overview of process simulation and flowsheeting:
- Definition and fundamentals
- Fields of application
- Case studies

Process simulation:
- Modeling strategies of process systems
- Mass and energy balances and degrees of freedom of process units and process systems

Process flowsheeting:
- Flowsheet partitioning and tearing
- Solution methods for process flowsheeting
- Simultaneous methods
- Sequential methods

Process optimization and analysis:
- Classification of optimization problems
- Linear programming, LP
- Non-linear programming, NLP
- Mixed-integer linear programming, MILP
- Mixed-integer nonlinear programming, MINLP

Commercial software for simulation (Aspen Plus):
- Thermodynamic property methods
- Reaction and reactors
- Separation / columns
- Convergence, optimisation & debugging
This course has the aim of deepening students' knowledge of the environmental assessment methodologies and their various applications.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.</td>
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</tbody>
</table>

#### Energy Economics and Policy

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the Built Environment</td>
<td>W</td>
<td>3</td>
<td>2</td>
<td>G. Habert, D. Kaushal</td>
</tr>
</tbody>
</table>

**Abstract**

In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. In 2016, other political bodies made these changes more difficult to predict. What does it mean for the built environment?

This course provides an introduction to the notion of sustainable development when applied to our built environment.

**Objective**

At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development.

Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmental aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development.

Students will learn on theory and application of current scientific pathways towards sustainable development.

**Content**

The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification
- Main issues:
  - Operation energy at building, urban and national scale
  - Mobility and density questions
  - Embodied energy for developing and developed world
- Synthesis: Transition to sustainable development

**Lecture notes**

A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>An exemplary literature list is provided below:</td>
</tr>
<tr>
<td>- Smith, R. Chemical process design and integration, Wiley (2005).</td>
</tr>
</tbody>
</table>

**102-0317-00L Advanced Environmental Assessments**

Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0317-00 Advanced Environmental Assessments (3KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

**Abstract**

This course deepens students' knowledge of the environmental assessment methodologies and their various applications.

**Objective**

This course has the aim of deepening students' knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the

- Ability to estimate the scientific quality and reliability of the environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers
### Content
- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

### Lecture notes
No script. Lecture slides and literature will be made available on Moodle.

### Literature
Literature will be made available on Moodle.

### Prerequisites / notice
Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

### 102-0317-03L
**Advanced Environmental Assessment (Computer Lab I)**

| W | 1 credit | 1U | S. Pfister |

**Abstract**
Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice

**Objective**
Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

### 102-0317-04L
**Advanced Environmental Assessment (Computer Lab II)**

| W | 2 credits | 2P | S. Pfister |

**Abstract**
Technical systems are investigated in projects, based on the software and tools introduced in the course 102-0317-03L Advanced Env. Assessment (Computer Lab I). The projects are created around a complete but simplified LCA study, where the students will learn how to answer a given question with target oriented methodologies using various software programs and data sources for env. assessment

**Objective**
Become acquainted with utilizing various software programs for environmental assessment to perform a Life Cycle Assessment and learn how to address the challenges when analyzing a complex system with available data and software limitations.

### 102-0327-01L
**Implementation of Environmental and Other Sustainability Goals**

| W | 2 credits | 2G | A. E. Braunschweig |

**Abstract**
Master students in Environmental Engineering choosing module Ecological Systems Design as already included in Environment and Computer Laboratory I (Year Course): 102-0327-00 and 102-0528-00.

**Objective**
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications, regarding products & services as well as organisations.

In particular, students completing the course should have the:
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to:
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management
Part I: Slides and background reading material will be available on lecture homepage

Part II: Documents will be available on Ilias

227-0759-00L International Business Management for Engineers

This course will be offered for the last time in fall 2021

Objective

The goal of the lecture is to get a basic understanding of international market mechanisms and their consequences for a successful enterprise. Students will learn by practical examples how to analyze international markets, competition as well as customer needs and how they convert into a successful portfolio an enterprise offers to the global market. They will understand the basics of international business management, why efficient organizations and effective business processes are crucial for the successful survival of an enterprise and how all this can be implemented.

Content

The first part of the course provides an overview about the development of international markets, the expected challenges and the players in the market. The second part is focusing on the economic aspects of an enterprise, their importance for the long term success and how to effectively manage an international business. Based on these fundamentals the third part of the course explains how an innovative product portfolio of a company can be derived from considering the most important external factors and which consequences in respect of product innovation, competitive product pricing, organization and business processes emerge. Each part of the course includes practical examples to demonstrate the procedure.

Prerequisites / notice

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

Literature

Will be made available.

Lecture notes

A script is provided for this lecture.

- An intro into sustainability issues of supply chain management
- Single score env. assessment methods (Swiss ecopoints)
- Environmental performance measurement of an organisation, including 'organisational LCA' (Ecobalance), based on practical examples of companies and new concepts
- Stakeholder management and sustainability oriented communication
- An intro into sustainability issues of supply chain management

Students will get small exercises related to course issues.

363-0537-00L Resource and Environmental Economics

Objective

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

Content

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

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

Autumn Semester 2021 Page 827 of 2152
Lecturers

Type

* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the-Art, the “in this paper” paragraph, the scientific presentation slides will be made available on moodle prior to lectures.

40D

The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students will work on teams on sustainability challenges related to water, energy, mobility, and food.

Objective

Students

- assess the limits and the potential of corporate sustainability for sustainable development
- develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method.
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams with different output formats (tv-style debate, consultancy pitch, technology model walk-through, campaign video)

Content

In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share their insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SustTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

Lecture notes

Presentation slides will be made available on moodle prior to lectures.

Lecture notes

Literature recommendations will be distributed during the lecture

Prerequisites / notice

TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.

**GESS Science in Perspective**

_see GESS Science in Perspective: Language Courses_
ETH/UZH

_see GESS Science in Perspective: Type A: Enhancement of Reflection Capability_

Recommended GESS Science in Perspective (Type B) for D-ITET

**Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1101-00L</td>
<td>How to Write Scientific Texts</td>
<td>E-w</td>
<td>0</td>
<td></td>
<td>U. Koch</td>
</tr>
</tbody>
</table>

Abstract

The 4-hour lecture covers the basics of writing & presenting a scientific text. The focus will be on the structure and elements of a scientific text and not on the language. Citation rules, good practice of scientific writing and an overview on software tools will be part of the training. The lecture will be divided into two afternoons. Some exercises will be built into the lecture.

Objective

Knowledge on structure and content of a scientific text. The course further is arranged to stimulate a discussion on how to properly write a legible scientific text versus writing an interesting novel. We will further discuss the practice of properly citing and critically reflect on recent plagiarism allegations.

Content

* Topic 1: Structure of a Scientific Text (The Title, the author list, the abstract, State-of-the-Art, the “in this paper” paragraph, the scientific part, the summary, Equations, Figures).

* Topic 2: Power Point Presentations.

* Topic 3: Citation Rules and Citation Software.

* Topic 4: Guidelines for Research Integrity.

Literature

ETH “Citation Etiquette”, see www.plagiate.ethz.ch.

Prerequisites / notice

ETH guidelines on “Guidelines for Research Integrity”, see www.ee.ethz.ch > Education > > Contacts, links & documents > Forms and documents > Brochures / guides.

Students should already have a Bachelor degree and plan to do either a semester project or a master thesis in the immediate future.

**Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1601-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30</td>
<td>40D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to enrol for and start with their master thesis:

- a. successful completion of the bachelor program;
- b. any additional requirements necessary to gain admission to the master program EST have been successfully completed;
- c. both the semester project and the internship have been successfully completed.

Registration in mystudies required

Abstract

The master program in Energy Science and Technology culminates in a six-month research project which addresses a scientific research question on one’s chosen area of specialization. The master’s thesis is supervised by a program-affiliated faculty member and the topic must be approved in advance by the tutor.

Objective

see above
<table>
<thead>
<tr>
<th>Energy Science and Technology Master - Key for Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>W</strong>  Eligible for credits</td>
</tr>
<tr>
<td><strong>E</strong>  Recommended, not eligible for credits</td>
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<tr>
<td><strong>Z</strong>  Courses outside the curriculum</td>
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<table>
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<tr>
<th>Key for Hours</th>
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<tbody>
<tr>
<td><strong>V</strong>  lecture</td>
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<tr>
<td><strong>G</strong>  lecture with exercise</td>
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<tr>
<td><strong>U</strong>  exercise</td>
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<tr>
<td><strong>S</strong>  seminar</td>
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<tr>
<td><strong>K</strong>  colloquium</td>
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<td><strong>P</strong>  practical/laboratory course</td>
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<td><strong>A</strong>  independent project</td>
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<td><strong>D</strong>  diploma thesis</td>
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<tr>
<td><strong>R</strong>  revision course / private study</td>
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</tbody>
</table>

**ECTS**  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-2001-02L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>J. Cvengros, J. E. E. Buschmann,</td>
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<td>P. Funck, E. C. Meister, R. Verel</td>
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<td></td>
<td>General Chemistry I:</td>
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<td>Chemical bond and</td>
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<td>molecular structure,</td>
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<td>chemical thermodynamics,</td>
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<td>chemical equilibrium.</td>
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<td></td>
<td>Introduction to general</td>
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<tr>
<td></td>
<td>and inorganic chemistry.</td>
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<td></td>
<td>Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.</td>
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<tr>
<td>Abstract</td>
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<tr>
<td>Objective</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>1. Stoichiometry</td>
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<tr>
<td></td>
<td>Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.</td>
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<td></td>
<td>2. Atoms</td>
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<tr>
<td></td>
<td>Elementary particles and atoms. Electron configuration of the elements. Periodic system.</td>
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<td></td>
<td>5. First law of</td>
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<td></td>
<td>thermodynamics</td>
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<td>6. Second law of</td>
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<td></td>
<td>thermodynamics</td>
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<td></td>
<td>Entropy. Change of entropy in chemical systems and universe. Reaction entropy.</td>
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<td></td>
<td>7. Gibbs energy and chemical potential.</td>
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<td></td>
<td>8. Chemical equilibrium</td>
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<tr>
<td></td>
<td>Law of mass action. Reaction quotient and equilibrium constant. Phase transition equilibrium.</td>
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<td></td>
<td>9. Acids and bases</td>
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<td></td>
<td>10. Dissolution and precipitation.</td>
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<tr>
<td></td>
<td>Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.</td>
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<tr>
<td>Literature</td>
<td>Online-Skript mit durchgerechneten Beispielen.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)</td>
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<tr>
<td>Taught</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
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</tr>
<tr>
<td>competencies</td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
<td></td>
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<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
<td></td>
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<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>401-0251-00L</td>
<td>Mathematics I</td>
<td>O</td>
<td>6</td>
<td>4V+2U</td>
<td>F. Da Lio</td>
</tr>
<tr>
<td></td>
<td>This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.</td>
<td></td>
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</tbody>
</table>
A thorough study of all script materials is requested before the course starts.

- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).

Prerequisites / notice

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

First Year Additional Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0030-00L</td>
<td>Laboratory Course: Elementary Chemical Techniques</td>
<td>O</td>
<td>3 credits</td>
<td>6P</td>
<td>A. de Mello, F. Jenny, M. H. Schroth</td>
</tr>
</tbody>
</table>

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0000-03L</td>
<td>Laboratory Course in Physics for Students in Earth Sciences</td>
<td>O</td>
<td>2 credits</td>
<td>4P</td>
<td>A. Biland, A. Müller</td>
</tr>
</tbody>
</table>

Abstract

The central aim is to provide an individual experience of the physical phenomena and the basic principles of the experiment. By conducting simple physical experiments the student will learn how to properly use physical instruments and how to evaluate the results correctly.

Objective

This laboratory course aims to provide basic knowledge of
- the setup of a physics experiment,
- the use of measurement instruments,
- various measuring techniques,
- the analysis or measurement errors,
- and the interpretation of the measured quantities.

Enrollment is only possible under https://www.lehrbetrieb.ethz.ch/laborpraktika.

No registration required via myStudies. For further information visit: https://ap.phys.ethz.ch

Only students from 3rd Semester BSc Earth Sciences on are admitted to this Laboratory Course.
Content

Fehlerrechnung, 9 ausgewählte Versuche zu folgenden Themen:

- Transversalschwingung einer Saite
- Mechanische Resonanz
- Innere Reibung in Flüssigkeiten
- Absoluter Nullpunkt der Temperaturskala
- Universele Gaskonstante
- Spezifische Verdampfungswärme
- Spezifische Wärme
- Interferenz und Beugung
- Drehung der Polarisationsebene
- Spektrale Absorption, Energieverteilung im Spektrum
- Spektroskopie, Leitfähigkeit eines Elektrolyten, Elektrische Leitfähigkeit und Wärmeleitfähigkeit, Radioaktivität
- Radioaktive Innenluft, Dichte und Leitfähigkeit, Fluss durch ein poröses Medium, Lärm.

Die Auswahl der Versuche kann zwischen den verschiedenen Studiengängen variieren.

Lecture notes

Anleitungen zum Physikalischen Praktikum

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0071-00L</td>
<td>Mathematics III: Systems Analysis</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
<td>Brunner, R., Knutti, S., Schemm, H., Wernli, P. Zschenderlein</td>
</tr>
</tbody>
</table>

Abstract

The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.
To understand and describe the basic principles of the hydrologic cycle and water flow in streams and aquifers.

This course provides an introduction to oceanography and hydrogeology, with a special focus on the basic physicochemical concepts that control the properties and behaviour of two major reservoirs of water on Earth.

The hydrogeology component will: 1) describe the hydrologic cycle, with a focus on the importance of groundwater to society; introduce the basic physical aspects of groundwater flow, including Darcy's law, hydraulic head, hydraulic conductivity, aquifers; 2) describe the basics of groundwater chemistry, including major ions and mean meteoric water line, basics of groundwater contamination; 3) introduce the interface with the oceans, including hydrothermal circulation at mid-ocean ridges, ocean-water intrusion into groundwater at coasts.

The oceanography component will: 1) provide an overview of the physical circulation of the oceans, including its importance for heat transfer around the surface of the Earth and for climate; 2) describe the basic processes that control the chemistry of the oceans, including its temporal and spatial variability; 3) introduce some simple concepts in biological oceanography, including the dependence of ocean ecology on nutrient distributions. There will be a specific focus on how the physics, chemistry and biology of the ocean might have changed through Earth history, and the impact of oceanic processes on Earth's climate.

The course will allow you to ask questions about the origin and the evolution of life on Earth, to understand contemporary hypotheses and create new methods of developing them further. Theory is supplemented with observations in the field, exercises and the application of simple mathematical models. The course will enable you to integrate geobiological knowledge into topics that will be taught in subsequent earth science courses and into the current understanding of Earth history. You will learn to better understand modern geological settings and, if necessary, to recommend biogeochemically well-founded and responsible interventions or protective measures.

To understand and describe the basic principles of the hydrologic cycle and water flow in streams and aquifers.

To conduct simple calculations of water transfer in streams and aquifers as well as of flood frequencies and magnitudes.

To discuss surface and groundwater as a water resource.

To interpret different ion distributions in aquifers in terms of basic water chemistry, fluid-mineral reactions, water contamination, and water origin.

To understand the major features of ocean basins and the tectonic controls on their structure.

To identify the major controls on the temperature, salinity and density structure of the oceans.

To describe how these controls interact to drive surface and interior ocean circulation.

To interpret different kinds of element distribution in the oceans in terms of basic chemistry, sinks, sources and internal biogeochemical cycling.

To discuss the cycles of carbon and oxygen in the ocean, with a view to the critical analysis of how the oceans respond to, cause and record the dynamics of these cycles in Earth history.

This course provides an introduction to oceanography and hydrogeology, with a special focus on the basic physicochemical concepts that control the properties and behaviour of two major reservoirs of water on Earth.

The hydrogeology component will: 1) describe the hydrologic cycle, with a focus on the importance of groundwater to society; introduce the basic physical aspects of groundwater flow, including Darcy's law, hydraulic head, hydraulic conductivity, aquifers; 2) describe the basics of groundwater chemistry, including major ions and mean meteoric water line, basics of groundwater contamination; 3) introduce the interface with the oceans, including hydrothermal circulation at mid-ocean ridges, ocean-water intrusion into groundwater at coasts.

The oceanography component will: 1) provide an overview of the physical circulation of the oceans, including its importance for heat transfer around the surface of the Earth and for climate; 2) describe the basic processes that control the chemistry of the oceans, including its temporal and spatial variability; 3) introduce some simple concepts in biological oceanography, including the dependence of ocean ecology on nutrient distributions. There will be a specific focus on how the physics, chemistry and biology of the ocean might have changed through Earth history, and the impact of oceanic processes on Earth's climate.

We will study traces in the lithosphere that have been left behind by organisms during the course of Earth history and mineral components, which were built through biological processes or used as sources of energy and nutrients by organisms. Traces of life from the past will be compared with the development of the diversity of today's organisms.

The course will allow you to ask questions about the origin and the evolution of life on Earth, to understand contemporary hypotheses and create new methods of developing them further. Theory is supplemented with observations in the field, exercises and the application of simple mathematical models. The course will enable you to integrate geobiological knowledge into topics that will be taught in subsequent earth science courses and into the current understanding of Earth history. You will learn to better understand modern geological settings and, if necessary, to recommend biogeochemically well-founded and responsible interventions or protective measures.
The course focuses on (a) geochemical cycles that play major roles in Earth history in aquatic and terrestrial ecosystems, (b) biosynthetic and metabolic processes, which are essential for life, (c) organisms which regulate and maintain geochemical cycling, and (d) chemical signals of past life in the geological record.

Accordingly, we must understand
- how biological cells and its components are built from essential elements and molecules,
- how cells function and which life styles organisms developed,
- where organisms can exist and which factors select for their presence,
- where biologically useable forms of energy come from, and under which conditions they can be exploited,
- how biological metabolism can change environmental conditions and composition,
- which biological products can lead to signals preserved in the rock record, and how biomolecules and elements are altered in sedimentary deposits,
- how organic and inorganic components are cycled through the biosphere, and how biogeochemical cycles function,
- how "biological innovations" evolved and changed in response to environmental changes.

Applied Case Studies, which supplement and illustrate the contents:
- Scientific applications of geochemical knowledge are found in fields like Microbial Ecology, Geochemistry, Palaeontology,

Prerequisites / notice
As integral Bestandteil der Vorlesung wird eine Exkursion durchgeführt.

Mit der Belegung akzeptieren die Studierenden die Allgemeinen Geschäftsbedingungen für Exkursionen und Feldkurse des D-ERDW: https://www.ethz.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_dt.pdf

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Autumn Semester 2021
Page 834 of 2152
Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences. The surface Earth is often thought of as a set of interacting systems, often with feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required.

Objective
To introduce students to an integrated view of the surface Earth, uniting perspectives from different disciplines of the earth sciences.

Content
Planet Earth has had a complex history since its formation ~4.6 billion years ago. The surface Earth is often thought of as a set of interacting systems, often with positive and negative feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required. This is a subject that pulls in observations and models from many areas of the Earth Sciences, including geochemistry, geophysics, geology and biology. The main goal of the course is to convey this integrated view of the surface of our planet.

We will achieve this integrated view through a series of lectures, exercises, and tutorials. We take as our framework some of the key events in Earth history, encouraging understanding of the controlling processes through integrated observations, ideas and models from disciplines across science.

Integrated Earth Systems

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
651-4180-02L | Integrated Earth Systems II | O | 5 credits | 4G+1U | H. Stoll, D. Vance, S. Willett

Abstract
The surface Earth is often thought of as a set of interacting systems, often with feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required.

Objective
To encourage students in the critical analysis of data and models in Earth Science.

Content
Planet Earth has had a complex history since its formation ~4.6 billion years ago. The surface Earth is often thought of as a set of interacting systems, often with positive and negative feedbacks between them. These interacting systems control the tectonics, geomorphology, climate, and biology of the surface Earth. To fully understand the nature of the Earth System, including the controls on its past evolution, its present state, and its future, an integrated perspective is required. This is a subject that pulls in observations and models from many areas of the Earth Sciences, including geochemistry, geophysics, geology and biology. The main goal of the course is to convey this integrated view of the surface of our planet.

We will achieve this integrated view through a series of lectures, exercises, and tutorials. We take as our framework some of the key events in Earth history, encouraging understanding of the controlling processes through integrated observations, ideas and models from disciplines across science.

Majors

**Major: Geology and Geophysics**
Advisors of the major in Geology and Geophysics are Dr. Vincenzo Picotti (Geology) and Dr. Jérôme Noir (Geophysics).

Methods

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
651-3527-00L | Earth Science Mapping Exercises II | W+ | 2 credits | 2P | J. Ruh

Abstract
Reading and interpretation of geological maps. All participants are able to:
- Read and understand complex geological maps;
- Assess, select, and project information from real case studies;
- Make tectonic overview sketches and construct meaningful cross-sections;
- Advanced analysis of geological maps and construction of geological sections. Special points: normal faults of the Rheintal graben, Val de Ruz, Helvetic nappes of the Säntis area. Reconstruction of the geological history of the map areas. References to the Geology of Switzerland.

Lecture notes
Exercises and instructions are handed out

Literature

Prerequisites / notice
Requirement: Earth science mapping exercises I

401-0624-00L | Mathematics IV: Statistics | W+ | 4 credits | 2V+1U | J. Ernest

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

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

Content

Lecture notes
Ausführliches Skript zur Vorlesung ist erhältlich.

Literature

Prerequisites / notice
Die Übungen (ca. die Hälfte der Kontaktstunden; einschliesslich Computerübungen) sind ein wichtiger Bestandteil der Lehrveranstaltung. Voraussetzungen: Mathematik I, II

651-4031-00L | Geographic Information Systems | W+ | 3 credits | 4G | A. Baltensweiler, M. Hägeli-Golay

Abstract
Introduction to the architecture and data processing capabilities of geographic information systems (GIS). Practical application of spatial data modeling and geoprocessing functions to a selected project from the earth sciences.

Objective
Knowledge of the basic architecture and spatial data handling capabilities of geographic information systems.

Content
Theoretical introduction to the architecture, modules, spatial data types and spatial data handling functions of geographic information systems (GIS). Application of data modeling principles and geoprocessing capabilities using ArcGIS: Data design and modeling, data acquisition, data integration, spatial analysis of vector and raster data, particular functions for digital terrain modeling and hydrology, map generation and 3D-visualization.

Lecture notes
Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro

Literature

This course gives an introduction to digital mapping in geosciences from data collection to the final map/model construction. The course focuses on the practical application of different digital mapping tools.

Objectives
- The students are able to
  - describe possible applications using digital mapping devices in geosciences
  - apply selected digital mapping tools in the office and in the field
  - visualize field data
  - evaluate 2D and 3D geodata for the development of a geological model

Content
- The following topics are covered
  - Sensor specifications of tablets and smartphones
  - Field apps and databases in digital mapping
  - Access to spatial geodata in Switzerland, but also worldwide
  - Visualization of 2D and 3D data
  - Several case studies on digital mapping
  - 1 day excursion with practical training underground and with surface geology

Prerequisites / notice
- Prerequisite is
  - 651-4301-00 Geographic Information Systems or an equivalent course
  - 651-3482-00 Geological Field Course II: Sedimentary Rocks or an equivalent course

Advanced

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>651-3521-00L</td>
<td>Tectonics</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>W. Behr, S. Willett</td>
</tr>
</tbody>
</table>

Abstract
- Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales.

Objective
- Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales.

Content
- Plate tectonic framework: earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longlifey and growth of continents, supercontinents.
- Rheology of layered lithosphere and upper mantle.
- Oduction systems
- Collisions systems
- Extensional systems
- Basin evolution
- Passive and active continental margin evolution

Literature

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-3501-00L</td>
<td>Geochemistry II</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>S. Bernasconi, M. Schönbachler</td>
</tr>
</tbody>
</table>

Abstract
- The course focuses on the most important systems of radioactive and stable isotopes used in geochemistry and geology. Applications of isotope geochemistry for solving fundamental geological problems are discussed on the basis of case studies.

Objective
- Development of a basic knowledge and understanding of the applications of the most important systems of stable and radiogenic isotopes.

Content
- The following methods will be discussed in detail: the radioactive-radiogenic systems Rb-Sr, Sm-Nd, U-Th-Pb and K-Ar, as well as the stable isotope systems of oxygen, carbon, nitrogen, sulfur and hydrogen.
- We will discuss how these methods are used in the following research fields: geochemistry of the earth, age dating, paleotemperature reconstructions, evolution of the crust and mantle reservoirs, sediment diagenesis, fluid rock interactions, hydrothermal activity, paleoceanography, biogeochemical cycles.

Lecture notes
- Slides are provided online.

Literature
- Dickin A. P., Radiogenic Isotope Geology, (2005), Cambridge University Press
- can be downloaded for free from http://csi.unm.edu

Prerequisites / notice
- Prerequisites:
  - Geochemie I: (Bachelor course)

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<tr>
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<tbody>
<tr>
<td>651-3440-02L</td>
<td>Geophysics III</td>
<td>W+</td>
<td>4</td>
<td>3G</td>
<td>A. Jackson, M.-A. Meier, P. Tackley</td>
</tr>
</tbody>
</table>

Abstract
- This course builds on Geophysik I and Geophysik II, broadening the students' education in seismology, geodynamics and geodynamo theory, by considering various specific topics of particular interest.

Objective
- To teach students the basics of observational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography, mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux, dynamo operation and magnetic field generation in Earth, planets, the Sun and stars and electromagnetism to probe the mantle.
Content
Observational seismology, earthquake source seismology, seismotectonics and the principle of seismic tomography. Mantle convection over Earth history, structure of the oceanic and continental lithosphere, plate tectonics, hotspots, global heat flux. Dynamo operation and magnetic field generation in Earth, planets, the Sun and stars; electromagnetism to probe the mantle.

#### Applied

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-3525-00L</td>
<td>Introduction to Engineering Geology</td>
<td>W+</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>S. Löw, L. de Palézieux dit Falconnet, M. Ziegler</td>
</tr>
</tbody>
</table>

**Abstract**
This introductory course starts from a descriptions of the behavior and phenomena of soils and rocks under near surface loading conditions and their key geotechnical properties. Lab and field methods for the characterization of soils, rocks and rock masses are introduced. Finally practical aspects of ground engineering, including tunneling and landslide hazards are presented.

**Objective**
Understanding the basic geotechnical and geomechanical properties and processes of rocks and soils. Understanding the interaction of rock and soil masses with technical systems. Understanding the fundamentals of geological hazards.

**Content**

**Geological mass wasting processes.**

**Lecture notes**
Written course documentation available under "Kursunterlagen".

**Literature**

#### Electives

The electives listed are recommended.

Additional courses can be chosen from the complete offerings of the ETH Zurich and University of Zurich.

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-3525-00L</td>
<td>Exploration and Environmental Geophysics</td>
<td>W+</td>
<td>4 credits</td>
<td>3V</td>
<td>P. Edme, H. Maurer, A. Shakas</td>
</tr>
</tbody>
</table>

**Abstract**
Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical and electromagnetic methods, Refraction and reflection seismics, Georadar. Discussion of survey design, sources and receivers and data processing.

**Objective**
Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to exploration and environmental geophysics in soil, ice and lithosphere at different scales. Getting familiar with measuring- and interpretation procedures. Pointing out the possibilities and limitations of geophysical methods.

**Content**

**Lecture notes**
Available through eDoz/ILIAS.

**Literature**

#### Quaternary Geology and Geomorphology

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4903-00L</td>
<td>Quaternary Geology and Geomorphology</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Ivy Ochs, M. Luetscher, H. Stoll</td>
</tr>
</tbody>
</table>

**Abstract**
In this course the student is familiarized with the manner in which glacial, periglacial, fluvial, gravitational, karst, coastal and aeolian processes produce characteristic landforms and sedimentary deposits. The student is introduced to subdivisions of the Quaternary, with a focus on climatic changes in the Alps. Competency in these themes is gained through practical exercises and discussion.

**Additional material** will be provided by the lecturers.

**Literature**


Further literature will be indicated during the lecture.
Taught competencies

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

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

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

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

701-0565-00L Fundamentals of Natural Hazards Management

Does not take place this semester.

W 3 credits 3G V. Griess, B. Krummenacher, S. Löw

Abstract
Risks to life and human assets result when settlement areas and infrastructure overlap regions where natural hazard processes occur. This course utilizes case studies to teach how a future natural hazards-specialist should analyze, assess and manage risks.

Objective
Concepts will be explained step-by-step through a set of case studies, and applied in lab by the students. The following principal steps are used when coping with natural hazard-risks. At each step, students will learn and apply the following skills:
- Risk analysis - What can happen?
  - Characterize the processes and environmental measures that lead to a natural hazard and integrate modeling results of these processes.
  - Identify threats to human life and assets exposed to natural hazards and estimate possible drawbacks or damages.
- Risk assessment - What are the acceptable levels of risk?
  - Apply principles to determine acceptable risks to human life and assets in order to identify locations which should receive added protection.
  - Explain causes for conflicts between risk perception and risk analysis.
- Risk management - What steps should be taken to manage risks?
  - Explain how various hazard mitigation approaches reduce risk.
  - Describe hazard scenarios as a base for adequate dimensioning of control measures.
- Identify the best alternative from a set of thinkable measures based on an evaluation scheme.
  - Explain the principles of risk-governance.

Content
Die Vorlesung besteht aus folgenden Blöcken:
1) Einführung ins Vorgehenskonzept (1W)
2) Risikoanalyse (6W + Exkursion) mit:
   - Systemabgrenzung
   - Gefahrenbeurteilung
   - Expositions- und Folgenanalyse
3) Risikobewertung (2W)
4) Risikomanagement (2W + Exkursion)
5) Abschlussbesprechung (1W)

Choice of courses from the complete offerings of ETH.

Bachelor's Seminar
The Bachelor's Seminar is only offered in the spring semester.

Number Title Type ECTS Hours Lecturers
651-3597-00L Bachelor's Seminar I O 2 credits 2S W. Schatz, J. D. Rickli

Abstract
In this seminar, students learn to search efficiently for scientific literature and to present scientific findings orally and in written form.

Objective
The students learn the principles of presenting scientific material orally. They become acquainted with the structure of scientific publications, and learn how to find, read and evaluate scientific literature. Furthermore, the course will introduce basic aspects of scientific writing.

Major: Climate and Water
Advisor of the BSc-major "Climate and Water" is Dr. Hanna Joos, Institute for climate and atmosphere (IAC).

Advanced

Number Title Type ECTS Hours Lecturers
701-0471-01L Atmospheric Chemistry W 3 credits 2G M. Ammann, T. Peter

Abstract
The lecture provides an introduction to atmospheric chemistry at bachelor level. It introduces the fundamentals of gas phase reactions, the concept of solubility and reactions in aerosols and in clouds. It explains the chemical and physical processes responsible for global (e.g. stratospheric ozone depletion) as well as regional (e.g. urban air pollution) environmental problems.

Objective
The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will understand the most important chemical processes in the troposphere and the stratosphere.
The students will also acquire a good understanding of atmospheric environmental problems including air pollution, tropospheric ozone formation, stratospheric ozone destruction and the relationship between air pollution and climate change.
Content
- Origin and properties of the atmosphere: composition (gases and aerosols), structure, large scale dynamics, UV radiation
- Thermodynamics and kinetics of gas phase reactions: enthalpy and free energy of reactions, rate laws, mechanisms of bimolecular and termolecular reactions.
- Tropospheric photochemistry: Photoysis reactions, photochemical O3 formation, role and budget of HOx, dry and wet deposition
- Aerosols and clouds; chemical properties, primary and secondary aerosol sources, solubility of gases, hygroscopicity, kinetics of gas to particle transfer, NO2 oxidation, secondary organic aerosol formation
- Air quality: role of planetary boundary layer, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Stratospheric chemistry: Chapman cycle, Brewer-Dobson circulation, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Global aspects: global budgets of ozone, methane, CO and NOx, air quality - climate interactions

Lecture notes / Prerequisites / notice
Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture.

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.

On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.

701-0475-00L Atmospheric Physics W 3 credits 2G U. Lohmann
Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

Students are able
- to explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to classify radiosondes with the help the thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Lecture notes
Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15367

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

Domain A - Subject-specific Competencies
- Concepts and Theories assessed

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Problem-solving assessed

Domain C - Social Competencies
- Communication assessed

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

Prerequisites / notice
50% of the time we use the concept of "flipped classroom" (en.wikipedia.org/wiki/Flipped_classroom), which we introduce at the beginning.

Further literature will be indicated during the lecture.

651-3561-00L Cryosphere W 3 credits 2V M. Huss, A. Bauder, D. Farinotti
Abstract
The course introduces the different components of the cryosphere - snow, glaciers, ice sheets, sea ice and lake ice, and permafrost - and their respective roles in the climate system. For each subsystem, essential physical aspects are emphasized, and their dynamics are described quantitatively and using examples.

Students are able to
- qualitatively explain relevant processes, feedbacks and relationships between the different components of the cryosphere,
- quantify and interpret physical processes, which determine the state of the cryospheric components, with simple calculations.

The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost, and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

Handouts will be distributed during the teaching semester

Further literature will be indicated during the lecture.

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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**701-0461-00L Numerical Methods in Environmental Sciences**

**Abstract**

This lecture imparts the mathematical basis necessary for the development and application of numerical models in the field of Environmental Science. The lecture material includes an introduction into numerical techniques for solving ordinary and partial differential equations, as well as exercises aimed at the realization of simple models.

**Objective**

This lecture imparts the mathematical basis necessary for the development and application of numerical models in the field of Environmental Science. The lecture material includes an introduction into numerical techniques for solving ordinary and partial differential equations, as well as exercises aimed at the realization of simple models.

**Content**

Classification of numerical problems, introduction to finite-difference methods, time integration schemes, non-linearity, conservative numerical techniques, an overview of spectral and finite-element methods. Examples and exercises from a diverse cross-section of Environmental Science.

Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Python (previous experience not necessary: a Python introduction is given). Example programs and graphics tools are supplied.

**Lecture notes**


**Literature**

List of literature is provided.

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**701-0473-00L Weather Systems**

**Abstract**

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

**Objective**

The students are able to:
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context.

**Content**

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

**Lecture notes**

Lecture notes and slides

**Literature**

Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

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### Electives

The electives listed are recommended. Additional courses can be chosen from the complete offerings of the ETH Zurich and University of Zurich.

**Number**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
</tbody>
</table>

**Abstract**

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

**Objective**

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

**Content**

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies. The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

**Lecture notes**

A script will be available.

**Literature**

Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis
In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Prerequisites / notice**

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
</tbody>
</table>

**Domain A - Subject-specific Competencies**

- quantify driving forces and resulting fluxes of water, solute, and heat in soils

**Domain B - Method-specific Competencies**

- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

**Domain C - Social Competencies**

- recognize possible fraud in statistics
- basic knowledge about the laws of randomness and stochastic thinking (thinking in probabilities)

**Domain D - Personal Competencies**

- self-direction and self-management

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

- W 3 credits
- 2V+1U
- A. Carminati, P. U. Lehmann Grunder

**Objective**

Students are able to:
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media

**Content**

Week 1: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;

Week 2: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

Week 7: Unsaturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow

Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project

Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow

Week 10: Root water uptake and transpiration

Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

Week 12: Summary of lectures; solution of old exam

Week 13: Written semester-end exam

Week 14: Short presentations of Hydrus class projects; discussion of written exam

**Literature**

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

**401-0624-00L Mathematics IV: Statistics**

- W 4 credits
- 2V+1U
- J. Ernest

**Objective**

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

**Content**

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

**Lecture notes**

Ausführliches Skript zur Vorlesung ist erhältlich.

**Literature**

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

**Objective**
- to name the bases, concepts and methods of environmental fluid dynamics.
- to understand and discuss the components of the basic physical equations in fluid dynamics
- to apply basic mathematical equations to simple problems of environmental fluid dynamics

**Content**
- Basic physical terminology and mathematical laws:
  - Continuum hypothesis, forces, constitutive laws, state equations and basic principles of thermodynamics, kinematics, laws of mass and momentum on rotating earth.
  - Concepts and illustrative flow systems: vorticity dynamics, boundary layers, instability, turbulence - with respect to environmental fluid systems.
  - Scale analysis: dimensionless variables and dynamical similarity, simplification of the fluid system, e.g. shallow water assumption, geostrophic flow.
  - Waves in environmental fluid systems.

**Literature**
In English language
See also: web-site.

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**Laboratory Course**

The practical takes place in spring semester.

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**Bachelor’s Seminar**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0459-00L</td>
<td>Seminar for Bachelor Students: Atmosphere and Climate</td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
<td>R. Knutti, H. Joos, O. Stebler</td>
</tr>
</tbody>
</table>

**Abstract**
In this seminar all students in the realm of atmospheric and climate science from D-ERDW and D-USYS convene to train presentation techniques (talks, posters) by means of classic and modern scientific articles.

**Objective**
In this seminar, students learn how to read scientific publications and how to transfer the scientific knowledge to a broader audience by means of oral and poster presentations. Students also get insight into the different research areas at the Institute for Atmospheric and Climate Science.

**Content**
- 1st week: course organisation and presentation of the institute
- 2nd and 3rd week: introduction to oral presentation technique
- week 4 to 10: students talks
- 11th week: introduction to poster presentation technique
- 12th and 13th week: poster design
- 14th week: concluding poster presentation

**Prerequisites / notice**
This course can only be offered to a limited number of students, however, in any case for everybody having to attend it compulsory. We beg you to sign in to this course early.

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**GESS Science in Perspective**

**Science in Perspective**

see *Science in Perspective: Type A: Enhancement of Reflection Capability*
#### Bachelor’s Thesis

The Bachelor Thesis and Bachelor-Seminar are offered once per year in the 6th semester, in the spring semester.

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

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Repetition of methods using optic properties of crystals and the polarising microscope.

This practical course bases on the course ‘Microscopy of metamorphic rocks’ (A. Galli), that is taught immediately before this course, where these basic principles are provided. This course provides basic knowledge in microscopy of igneous rocks. Apart from the identification of common igneous minerals in thin sections, mineral assemblages, textures and structures will be investigated and the results of microscopy will be combined with igneous phase equilibria to understand generation, differentiation and emplacement of igneous rocks. In addition, we will apply igneous phase equilibria that have been introduced in other lectures (such as magmatism and metamorphism I&II at ETH or an equivalent igneous petrology course) to natural rock samples in order to constrain qualitatively parental magma compositions and crystallization conditions. The range of investigated rocks encompasses mantle rocks, tholeiitic, calc-alkaline and alkaline plutonic and volcanic rocks that contain the most common igneous minerals.

The course does not include an introduction in optical mineralogy and the use of a polarizing microscope and, therefore, bases on the course “Microscopy of metamorphic rocks” taught by A. Galli immediately before this course where these basic principles are provided. Alternatively, e.g. for external students, an equivalent course is required to follow this practical course.

The delivery of 3 acceptably solved homework assignments is acknowledged with an increase of the final grade by 0.25.

Other microscope courses taught at ETH Zurich at the D-ERDW are:

- Microscopy of magmatic rocks (A. Galli, prerequisite for this course)
- Reflected Light Microscopy and Ore Deposits (T. Driesner)
- Sedimentary petrography and microscopy (V. Picotti & M.G. Fellin)
- Sedimentary Petrography and Microscopy (V. Picotti & M.G. Fellin)
Abstract
Introduction to reflected light microscopy. Use of the microscope. Identification of opaque minerals through the use of determination tables. Description of textures and paragenetic sequences.

Taking the course in parallel with Ore Deposits I (651-4037-00L) is recommended.

Objective
Recognition of the most important ore minerals in polished section. Interpretation of mineral textures in geological context

Content
Introduction to reflected light microscopy as a petrographic technique. Learning main diagnostic criteria. Study of small selection of important and characteristic minerals. Interpreting polished (thin) sections as exercise

Lecture notes
To be handed out in class

Prerequisites / notice
Credits and mark based on independent description of selected sample(s) towards the end of the course

651-4113-00L Sedimentary Petrography and Microscopy W+ 2 credits 2G V. Picotti, M. G. Fellin

Abstract
Microscopy of carbonate (1st half of semester) and siliciclastic rocks (2nd half) rocks as well as siliceous, phosphatic and evaporitic sediments.

Objective
Description of grains and cement/matrix, texture, classification of the main sedimentary rocks. Discussion and interpretation of the environment of sedimentation. Diagnostic Processes.

Content
Microscopy of carbonate and siliciclastic rocks, siliceous and phosphatic rocks, their origin and classification. Diagenesis.

Lecture notes
English textbooks recommended

Literature

Prerequisites / notice
The earlier attendance of other MSc microscopy courses (e.g. magmatic and metamorphic rocks) is not required if during the BSc a general course on microscopy of rocks was completed.

Part B: Methods

Number Title Type ECTS Hours Lecturers
651-4055-00L Analytical Methods in Petrology and Geology W+ 3 credits 2G J. Allaz, S. Bernasconi, M. Guillong, L. Zehnder

Abstract
Practical work in analytical chemistry for Earth science students.

Objective
Knowledge of some analytical methods used in Earth sciences, introduction to data interpretation, writing of a scientific report.

Content
Introduction to analytical geochemistry and atom physics, notably:
- X-ray diffraction (XRD),
- X-ray fluorescence analysis (XRF),
- Electron Probe Microanalyzer (EPMA),
- Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS),
- Mass spectroscopy for light isotopes.

Lecture notes
Short handouts for each analytical method.

Taught competencies
Domain A - Subject-specific Competencies
- Techniques and Technologies
  - assessed

Domain B - Method-specific Competencies
- Analytical Competencies
  - assessed
- Problem-solving
  - assessed
- Project Management
  - assessed

Domain C - Social Competencies
- Cooperation and Teamwork
  - assessed

Domain D - Personal Competencies
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - assessed
- Self-direction and Self-management
  - assessed

651-4117-00L Sediment Analysis W+ 3 credits 2G M. G. Fellin, A. Gilli, V. Picotti

Prerequisite: Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

Abstract
Theoretical background and application of some basic methods for sediment analysis.

Objective
The main goal is to learn how to apply the theory of the analysis of sediments and grain-size of sediments to constrain the sedimentary processes and environments.

Content
A one-day fieldtrip to a local outcrop to learn how to describe sediments in the field and to collect samples for grain-size and compositional analysis. Application of the same analytical techniques on samples of unknown origin: the sampling sites will be revealed at the end of the course. Discussion of the theoretical background and of the results in class. At the end of the course, the student will have to hand in a report with the presentation and discussion of all the data produced during the course.

Lecture notes
For the various analytical methods English texts will be provided in class.

Literature
Introduction to clastic sedimentology. R.J. Cheel, Brock University

651-4063-00L X-Ray Powder Diffraction W+ 3 credits 2G M. Plötze

Number of participants limited to 18.

Abstract
In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.

Objective
Upon successful completion of this course students are able to:
- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

Content
Fundamental principles of X-ray diffraction
Setup and operation of X-ray diffractometers
Interpretation of powder diffraction data
Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

Lecture notes
Selected handouts will be made available in the lecture.

Literature
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems." The students are able to:

- understand the chemistry and biology of the marine carbonate system
- be familiar with cool-water and warm-water carbonates
- be able to relate carbonate sedimentation to climate and oceanographic changes
- be able to use geological archives as source of information on global change
- be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records.

The compulsory courses of the module take place in spring semester.

### Biogeochemistry: Courses of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4043-00L</td>
<td>Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Picotti, A. Gilli, I. Hernández Almeida, H. Stoll</td>
</tr>
</tbody>
</table>

Abstract: The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes in palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

Objective:
- You will understand chemical and biological processes in marine carbonate systems.
- You will be able to relate carbonate mineralogy with facies and environmental conditions.
- You will be familiar with cool-water and warm-water carbonates.
- You will see carbonate and organic-rich sediments as part of the global carbon cycle.
- You will be able to recognize links between climate and marine carbonate systems (e.g., acidification of oceans and reef growth).
- You will be able to use geological archives as source of information on global change.
- You will have an overview of marine sedimentation through time.

Content:
- Carbonates, chemistry, mineralogy, biology.
- Carbonate sedimentation from the shelf to the deep sea.
- Marine facies.
- Cool-water and warm-water carbonates.
- Organic-carbon and black shales.
- C-cycle, carbonates, Corg: CO2 sources and sinks.
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr.
- Marine sediments through geological time.
- Carbonates and evaporites.
- Lacustrine carbonates.
- Economic aspects of limestone.

Prerequisites / notice: Successful completion of the MSc-course "Sedimentology I" (651-4041-00L).

Lecture notes: no script. Scientific articles will be distributed during the course.

Literature: We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems".

The grading of students is based on in-class exercises and end-semester examination.

Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective:
- The student will be able to describe the natural factors leading to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes.
- Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records.
- Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted.
- Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Prerequisites / notice: Successful completion of "Sedimentology I" (651-4041-00L) and "Sedimentology II" (651-4043-00L).

Lecture notes: no script. Scientific articles will be distributed during the course.

Literature: We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems".

The grading of students is based on in-class exercises and end-semester examination.
Content
1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems? Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

>>> Palaeoclimatology

>>> Palaeoclimatology: Compulsory Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4057-00L</td>
<td>Climate History and Palaeoclimatology</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida, H. Zhang</td>
</tr>
</tbody>
</table>

Abstract
Climate history and palaeoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors that lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
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5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

>>> Sedimentology

>>> Sedimentology: Compulsory Courses

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<tr>
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<tbody>
<tr>
<td>651-4043-00L</td>
<td>Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Picotti, A. Gilli, I. Hernández Almeida, H. Stoll</td>
</tr>
</tbody>
</table>

Abstract
The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes, palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

Objective
- You will understand chemistry and biology of the marine carbonate system
- You will be able to relate carbonate mineralogy with facies and environmental conditions
- You will be familiar with cool-water and warm-water carbonates
- You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle
- You will be able to recognize links between climate and marine carbonate systems (e.g. acidification of oceans and reef growth)
- You will be able to use geological archives as source of information on global change
- You will have an overview of marine sedimentation through time
- Genetic and physical processes of sedimentation
- carbonate, chemical, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg : CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments through geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

Lecture notes
No script. scientific articles will be distributed during the course.

Literature
We will read and critically discuss scientific articles relevant for "biological and chemical processes in marine and lacustrine systems".

Prerequisites / notice
The grading of students is based on in-class exercises and end-semester examination.
### Sedimentology I: Physical Processes and Sedimentary Systems

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>651-4041-00L</td>
<td>Sedimentology I: Physical Processes and Sedimentary Systems</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Picotti</td>
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</table>

**Abstract**

Sediments preserved a record of past landscapes. This course focuses on understanding the processes that modify sedimentary landscapes with time and how we can read these changes in the sedimentary record.

**Objective**

The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change. They discuss the advantages and pitfalls of the method and look beyond. In particular we pay attention to introducing the importance of considering entire sediment routing systems and understanding their functioning.

**Content**

Details on the program will be handed out during the first lecture.

We will attribute the papers for presentation on the 26th, so please be here on that day!

**Literature**

The sedimentary record of sea-level change

Angela Coe, the Open University.

Cambridge University Press

**Prerequisites / notice**

The grading of students is based on in-class exercises and end-semester examination.

### Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems

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<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4043-00L</td>
<td>Sedimentology II: Biological and Chemical Processes in Lacustrine and Marine Systems</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Picotti, A. Gilli, I. Hernández Almeida, H. Stoll</td>
</tr>
</tbody>
</table>

**Prerequisite: Successful completion of the MSc-course “Sedimentology I” (651-4041-00L).**

**Abstract**

The course will focus on biological and chemical aspects of sedimentation in marine environments. Marine sedimentation will be traced from coast to deep-sea. The use of stable isotopes palaeoceanography will be discussed. Neritic, hemipelagic and pelagic sediments will be used as proxies for environmental change during times of major perturbations of climate and oceanography.

**Objective**

- You will understand chemistry and biology of the marine carbonate system
- You will be able to relate carbonate mineralogy with facies and environmental conditions
- You will be familiar with cool-water and warm-water carbonates
- You will see carbonate and organic-carbon rich sediments as part of the global carbon cycle
- You will be able to recognize links between climate and marine carbonate systems (e.g. acidification of oceans and reef growth)
- You will be able to use geological archives as source of information on global change
- You will have an overview of marine sedimentation through time

**Content**

- carbonates, chemistry, mineralogy, biology
- carbonate sedimentation from the shelf to the deep sea
- carbonate facies
- cool-water and warm-water carbonates
- organic-carbon and black shales
- C-cycle, carbonates, Corg: CO2 sources and sink
- Carbonates: their geochemical proxies for environmental change: stable isotopes, Mg/Ca, Sr
- marine sediments throughout geological time
- carbonates and evaporites
- lacustrine carbonates
- economic aspects of limestone

**Lecture notes**

no script, scientific articles will be distributed during the course

**Literature**

We will read and critically discuss scientific articles relevant for “biological and chemical processes in marine and lacustrine systems.”

**Prerequisites / notice**

The grading of students is based on in-class exercises and end-semester examination.

### Sedimentology: Courses of Choice

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>651-4901-00L</td>
<td>Quaternary Dating Methods</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>I. Hajdas, M. Christl, S. Ivy Ochs</td>
</tr>
</tbody>
</table>

**Abstract**

Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archaeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

**Objective**

Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

At the end of the course students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. be able to calculate an age based on data of the six methods studied.
3. choose which dating method (or combination of methods) is suitable for a certain field problem.
4. critically read and evaluate the application of dating methods in scientific publications.

**Content**

1. Introduction: Time scales for the Quaternary, Isotopes and decay
2. Radiocarbon dating: principles and applications
3. Cosmogenic nuclides: 3He,10Be, 14C, 21Ne, 26Cl, 36Cl
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology and ice cores chronologies
7. Cs-137 and Pb-210 (soil, sediments, ice core)
8. Summary and comparison of results from several dating methods at specific sites

**Prerequisites / notice**

Visit to radiocarbon lab, cosmogenic nuclide lab, accelerator (AMS) facility.

Visit to Limno Lab and sampling a sediment core

Optional (individual): 1-5 days hands-on radiocarbon dating at the C14 lab at ETH Hoenggerebg

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets (Exercises)

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<tr>
<td>651-4063-00L</td>
<td>X-Ray Powder Diffraction</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
</tbody>
</table>

**Abstract**

In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.
Objective

Upon successful completion of this course students are able to:
- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

Content

Fundamental principles of X-ray diffraction
Setup and operation of X-ray diffractometers
Interpretation of powder diffraction data
Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

Lecture notes

Selected handouts will be made available in the lecture

Literature

BRINDLEY G.W. and BROWN G. (ed) Crystal structures of clay minerals and their X-ray identification. London : Mineralogical Society
Lecture notes

https://pubs.rsc.org/en/Content/eBook/978-0-85404-231-9

http://pubs.rsc.org/en/Content/eBook/978-0-85404-231-9


Prerequisites / notice

The course includes a high portion of practical exercises in sample preparation as well as measurement and evaluation of X-ray powder diffraction data.

Software will be provided for future use on own Laptop.

꾸꾸꾸 Structural Geology

꾸꾸꾸 Structural Geology: Compulsory Courses

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<tr>
<td>651-4132-00L</td>
<td>Field Course IV: Non Alpine Field Course</td>
<td>W+</td>
<td>3 credits</td>
<td>6P</td>
<td>W. Behr</td>
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Does not take place this semester.
PRIORITY is given to D-ERDW students. If space is available UZH Geography and Earth System Sciences students may attend this field course at full cost.

No registration through myStudies. The registration for excursions and field courses goes through http://exkursionen.erdw.ethz.ch only.

Prerequisites / notice

Students who want to participate hand in a short motivation letter (max. 1 page A4). The final selection will be based on this motivation letter.
Deadline for motivation letter: 31 October 2018
Final decision 20 November 2018

Students registering for the course confirm having read and accepted the terms and conditions for excursions and field courses of D-ERDW https://www.erdw.ch/content/dam/erdw/special-interest/erdw/department/dokumente/studium/exkursionen/AGB_ERDW_Exkursionen_en.pdf

꾸꾸꾸 Structural Geology: Courses of Choice

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<tr>
<td>651-4111-00L</td>
<td>Experimental Rock Physics and Deformation</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>A. S. Zappone, C. Madonna, L. Tokle</td>
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Abstract

We illustrate some physical properties, deformation mechanisms, and define flow laws. We show the fundamental techniques for the measurement in laboratory of density, permeability, elastic properties and deformation. We presented actual case studies and discuss upsampling from laboratory to field.

Objective

The objective of this course is to introduce rock physics and rock deformation, and discuss the aid of laboratory tests to interpretation at large scale.

Rock Physics provides the understanding to connect geomechanical and geophysical data to the intrinsic properties of rocks, such as mineral composition and texture. Rock Physics is a key component in geo-resources exploration and exploitation, and in geo-hazard assessment.

For rock deformation we will illustrate how to determined flow-laws of rocks from experiments and how to extrapolate to natural conditions. Since the time scale of laboratory experiments is several orders of magnitude faster than nature, we will compare the microstructure of natural rocks with that produced during the experiments to prove that the same mechanisms are operating. For this purpose, the fundamental techniques of experimental rock deformation will be illustrated and test on natural rock samples in the plastic deformation regime (high temperature) as well in the brittle regime (room temperature) will be presented. We will perform tests in the lab, to acquire the data, to correct for calibration and to process the data and finally to interpret the data.

The course is at Master student level, but will be useful for PhDs students who want to begin to work in experimental deformation or who want to know the meaning and the limitation of laboratory flow-laws for geodynamic modelling.

Content

The course will focus on research-based term project, lectures will alternate with laboratory demonstrations.

We will illustrate how intrinsic properties of rocks (mineral composition, porosity, pore fluids, crystallographic orientation, microstructures) are connected to the following physical properties:
- permeability;
- elastic properties for seismic interpretations;
- anisotropy of the above physical properties.

We will measure some of those parameters in laboratory and discuss real case studies and applications.

Principles of deformation mechanisms, flow laws, and deformation mechanism maps will be presented in lectures.
In laboratory we will show:
- Experimental deformation rigs (gas, fluid and solid confining media);
- Main part of the apparatus (mechanical, hydraulic, heating system, data logging);
- Calibration of an apparatus (distortion of the rig; transducers calibration);
- Various types of tests (axial deformation; diagonal cut and torsion; deformation; constant strain rate tests; creep tests; stepping tests);

Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the

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<tr>
<td>651-3521-00L</td>
<td>Tectonics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>W. Behr, S. Willett</td>
</tr>
</tbody>
</table>

Abstract
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Objective
Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alps-Himalaya orogenic system.

Content
Plate tectonic frame work: earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longlifey and growth of continents, supercontinents. Rheology of layered lithosphere and upper mantle. Obduction systems Collisions systems Extensional systems Basin evolution Passive and active continental margin evolution

Literature

Open Choice Modules Geology

Basin Analysis

Basin Analysis: Compulsory Courses

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<tr>
<th>Number</th>
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<tr>
<td>651-4341-00L</td>
<td>Source to Sink Sedimentary Systems</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>T. I. Eglinton, J. Hemingway, S. Willett</td>
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Abstract
The transfer and redistribution of mass and chemical elements at the Earth’s surface is controlled by a wide range of processes that will affect the magnitude and nature of fluxes exported from continental fluvial systems. This course addresses the production, transport, and deposition of sediments from source to sink and their interaction with biogeochemical cycles.

Objective
This course aims at integrating different earth science disciplines (geomorphology, geochemistry, and tectonics) to gain a better understanding of the physical and biogeochemical processes at work across the sediment production, routing, and depositional systems. It will provide insight into how it is actually possible to “see a world in a grain of sand” by taking into account the cascade of physical and chemical processes that shaped and modified sediments and chemical elements from their source to their sink.

Content
Lectures will introduce the main source to sink concepts and cover physical and biogeochemical processes in upland, sediment producing areas (glacial and periglacial processes; mass movements; hillslopes and soil processes/development; critical zone biogeochemical processes). Field excursion (3 days, 8-10 October): will cover the upper Rhône from the Rhône glacier to the Rhône delta in Lake Geneva) as small scale source-to-sink system.
Practicals comprise (I) a small autonomous project on the Rhône catchment based on samples collected during the field trip and (II) an independent report on how you would design, build, and implement your own source-to-sink study.
Lecture notes
Lecture notes are provided online during the course. They summarize the current subjects week by week and provide the essential theoretical background.

Literature
Suggested references :
- "Sediment routing systems: the fate of sediments from Source to Sink" by Philip A. Allen (Cambridge University Press)
- "Principles of soilscape and landscape evolution by Garry Willgoose" (Cambridge University Press)
- "Geomorphology, the mechanics and chemistry of landscapes" by Robert S. Anderson & Suzanne P. Anderson (Cambridge University Press)

Basin Analysis: Courses of Choice

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<tr>
<td>651-4243-00L</td>
<td>Seismic Stratigraphy and Facies</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>G. Eberli</td>
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</table>

Abstract
The course teaches the techniques of seismic interpretation for solving geological and environmental problems. A special focus is given to the seismic facies analysis and seismic sequence stratigraphy of different depositional systems. In addition, examples are presented how seismic data can be integrated into research projects in basin analysis, paleoceanography and paleoclimatology.

Objective
1. Acquire techniques for a comprehensive interpretation of seismic sections for solving geologic, stratigraphic and environmental problems
2. Correlation of seismic facies and seismic attributes to lithologic facies in different sedimentary systems
3. Learn the principles and techniques of seismic sequence stratigraphy and the differences between lithostratigraphy and sequence stratigraphy
4. Learn to integrate seismic data into paleoceanographic and paleoclimatic research.
Content
The four day course consists of lectures that are accompanied by a variety of exercises.

Day 1:
Introduction seismic facies analysis with exercise
Seismic resolution
Seismic facies of contourite drift systems and their value as physical indicators of global current changes.

Day 2:
Seismic attributes and seismic geomorphology
Siliciclastic deltas, shelves and turbidite systems, 2D-3D
Exercise: Seismic section Tarxagron Basin and reconstructing the basin evolution with respect to the climate conditions at the end of the Miocene.
Seismic facies carbonate systems
Carbonates as recorders of sea level and paleoclimate
Deepwater environments, including cold-water coral habitats

Day 3:
Carbonates versus volcanic seismic facies
Introduction seismic attributes
Faults and structures on seismic sections
Seismic facies of mixed systems with
Exercises from Canada and the Paradox Basin

Day 4:
Sea level and sedimentation
Telling ages on seismic section
Seismic stratigraphy and sequence stratigraphy
Exercise: Sequence analysis Straits of Andros
Final discussion

Lecture notes
An original script (110 pages) designed for the class will be distributed at the beginning of the course.

Literature
Books Seismic Interpretation of Depositional Systems:

Earthquake Seismology

Earthquake Seismology: Compulsory Courses

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<tr>
<td>651-4021-00L</td>
<td>Engineering Seismology</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>D. Fäh, V. Perron</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>This course is a general introduction to the methods of seismic hazard analysis. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties.</td>
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<td></td>
<td>Objective</td>
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<td>Content</td>
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<td>In the course it is explained how the disciplines of seismology, geology, strong-motion geophysics, and earthquake engineering contribute to the evaluation of seismic hazard. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties. The course includes the discussion related to intensity and macroseismic scales, historical seismicity and earthquake catalogues, ground motion parameters used in earthquake engineering, definitions of the seismic source, ground motion attenuation, site effects and microzonation, and the use of numerical tools to estimate ground motion parameters, both in a deterministic and probabilistic sense.</td>
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</table>

During the course recent earthquakes and their impacts are discussed and related to existing hazard assessments for the areas of interest.

651-4015-00L | Earthquakes I: Seismotectonics | O    | 3    | 2G    | A. P. Rinaldi, T. Diehl |
| Abstract    | If you're interested in knowing more about the relationship between seismicity and plate tectonics, this is the course for you. (If you're not that interested, but your program of study requires that you complete this course, this is also the course for you.) |
| Objective   | The aim of the course is to obtain a basic understanding of the physical process behind earthquakes and their basic mathematical description. By the conclusion of this course, we hope that you will be able to: |
|             | - describe the relationship between earthquakes and plate tectonics in a more sophisticated and complete way |
|             | - explain earthquake source representations of varying complexity; |
|             | - address earthquakes in the context of different tectonic settings; |
|             | - explain the statistical behaviour of global earthquakes |
|             | - describe and connect the ingredients for a seismotectonic study |
The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required for a complete understanding of the relation between earthquakes and plate tectonics. Our goal is to help you understand deformation on the small scale (fault) to the scale of plate tectonics. We will tell you about several ways to represent an earthquake source; we'll present these in order of increasing sophistication. You will enjoy (at least) a computer/class exercise and a guest lecture.

Topics covered in the course include:
- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms;
- seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations;
- earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity;
- different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes
Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature

Prerequisites / notice
Basic knowledge of continuum mechanics and rock mechanics, as well as notion of tensor analysis is strongly suggested. We recommend to have taken the course Continuum Mechanics (generally taught during the Fall semester).

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.

Earthquake Seismology: Compulsory Courses
One additional elective course of at least 3KP has to be completed for this Module according to prior agreement with the Subject Advisor (Autumn or Spring Semester).

Geographic Information Systems
The courses of this module are offered by UZH and must be registered at UZH.

Geographic Information Systems: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4267-00L</td>
<td>Specializing in Geographic Information Science V (University of Zürich)</td>
<td>W+</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
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</table>

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Geomagnetics

Geomagnetics: Compulsory Courses
Courses are only offered in spring semester.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4901-00L</td>
<td>Quaternary Dating Methods</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>I. Hajdas, M. Christl, S. Ivy Ochs</td>
</tr>
</tbody>
</table>

Abstract
Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Objective
Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

At the end of the course students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. be able to calculate an age based on data of the six methods studied.
3. choose which dating method (or combination of methods) is suitable for a certain field problem.
4. critically read and evaluate the application of dating methods in scientific publications.

Content
1. Introduction: Time scales for the Quaternary, Isotopes and decay
2. Radiocarbon dating: principles and applications
3. Cosmogenic nuclides: 3He, 10Be, 14C, 21Ne, 26Cl, 36Cl
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology and ice cores chronologies
7. C137 and Pb-210 (soil, sediments, ice core)
8. Summary and comparison of results from several dating methods at specific sites

Prerequisites / notice
Visit to radiocarbon lab, cosmogenic nuclide lab, accelerator (AMS) facility.

Visit to Limno Lab and sampling a sediment core
Optional (individual): 1-5 days hands-on radiocarbon dating at the C14 lab at ETH Hoenggerebrg

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets (Exercises)
Additional elective courses of at least 6KP have to be completed for this Module according to prior agreement with the Subject Advisor (Autumn or Spring Semester).

#### Glaciology

##### Glaciology: Compulsory Courses

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<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tr>
<td>651-3561-00L</td>
<td>Cryosphere</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Huss, A. Bauder, D. Farinotti</td>
</tr>
</tbody>
</table>

**Abstract**
The course introduces the different components of the cryosphere - snow, glaciers, ice sheets, sea ice and lake ice, and permafrost - and their respective roles in the climate system. For each subsystem, essential physical aspects are emphasized, and their dynamics are described quantitatively and using examples.

**Objective**
Students are able to
- qualitatively explain relevant processes, feedbacks and relationships between the different components of the cryosphere,
- quantify and interpret physical processes, which determine the state of the cryospheric components, with simple calculations.

**Content**
The course provides an introduction into the various components of the cryosphere: snow, glaciers, ice sheets, sea ice and lake ice, permafrost, and their roles in the climate system. Essential physical aspects are emphasized for each subsystem: e.g. the material properties of ice, mass balance and dynamics of glaciers, or the energy balance of sea ice.

**Lecture notes**
Handouts will be distributed during the teaching semester

**Literature**

Further literature will be indicated during the lecture.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td>Project Management</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
<td>Negotiation</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td>Self-direction and Self-management</td>
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#### Glaciology: Courses of Choice

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-1581-00L</td>
<td>Seminar in Glaciology</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>A. Bauder</td>
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</table>

**Abstract**
Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.

**Objective**
In-depth knowledge of selected topics of research in Glaciology. Introduction to different types of scientific presentation. Improve ability of the discussion of scientific topics.

**Content**
Selected topics of scientific research in Glaciology

**Lecture notes**
Copies/pdf of scientific papers will be distributed during the course

**Prerequisites / notice**
Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:
- 651-3561-00L Kryosphäre
- 101-0289-00L Applied Glaciology
- 651-4101-00L Physics of Glaciers

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<tbody>
<tr>
<td>651-4077-00L</td>
<td>Quantification and Modeling of the Cryosphere: Dynamic Processes (University of Zurich)</td>
<td>W</td>
<td>3 credits</td>
<td>1V</td>
<td>University lecturers</td>
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</table>

**Abstract**
Overview of the most important earth surface processes and landforms in cold regions (regions with glaciers and intense frost) with emphasis on high-mountain aspects. Discussion of present research challenges.

**Objective**
Knowledge of the most prominent climate-related geomorphological processes and phenomena in high-mountain regions, understanding of primary research challenges.

**Content**
Erosion and sedimentation by glaciers as a function of topography, englacial temperature, sediment balance, sliding and melt water runoff. Processes and landforms in regions of seasonal and perennial frost (frost weathering, rock falls, debris cones/talus, solifluction, permafrost creep/rock glaciers, debris flows).

**Lecture notes**
Glacial and periglacial geomorphodynamics in high-mountain regions. Ca. 100 pages.

**Literature**
references in skript
The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydrometeorology
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

The objectives of the courses are to:
- Learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- Apply the above knowledge to some case studies inspired by large works performed at ETH’s Glaciology section;
- Generate the own computer code to solve the above case studies, and interpret the results;
- Understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

Completed BSc studies. Basic knowledge in computer scripting in any language (e.g., Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.

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</table>

Advanced understanding of evolution, mechanics, and rheology of divergent, convergent, and wrenching tectonic systems from the lithospheric scale to regional shallow crustal and outcrop-scales. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alp-Himalaya orogenic system.

Comprehensive understanding of evolution, mechanics, and rheology of divergent, convergent, and wrenching tectonic systems from the lithospheric scale to local shallow crustal and outcrop-scales. Assessment of mechanisms responsible for plate movements (the Earth as a heat transfer machine, dynamics of earth mantle, plate driving forces) and subsequent large-scale structures (oceanic basins and cycle of the oceanic lithosphere, convergence and mountain systems and continental growth, etc) through theoretical and experimental information. Evaluation of plate tectonic and other orogenic processes through the study of reference examples of taken in Alp-Himalaya orogenic system.
Content

Plate tectonic frame work: earth cooling and mantle-plate interaction, three kinds of plate boundaries and their roles and characteristics, cycle of oceanic lithosphere, longlifey and growth of continents, supercontinents.

Rheology of layered lithosphere and upper mantle.

Obduction systems

Collisions systems

Extensional systems

Basin evolution

Passive and active continental margin evolution

Literature


<<<< Palaeontology

<<<< Palaeontology: Compulsory Courses

The compulsory courses take place in spring semester.

<<<< Palaeontology: Courses of Choice

The courses of choice are offered by UZH and must be registered at UZH.

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
651-1380-00L | Paleontological Excursions on Weekends (University of Zurich) | W | 1 credit | 1P | University lecturers

Abstract

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: BIO279

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Objective

Besuch von Fossilvorkommen im In- und Ausland, um die Erhaltung der Fossilien, die fazielle Ausbildung und die Stratigraphie der fossilführenden Schichten kennenzulernen und zu diskutieren sowie gegebe- nenfalls Fossilien zu sammeln.

Content


<<<< Quaternary Geology and Geomorphology

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
651-4901-00L | Quaternary Dating Methods | W | 3 credits | 2G | I. Hajdas, M. Christl, S. Ivy Ochs

Abstract

Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Objective

Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

At the end of the course students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. be able to calculate an age based on data of the six methods studied.
3. choose which dating method (or combination of methods) is suitable for a certain field problem.
4. critically read and evaluate the application of dating methods in scientific publications.

Content

1. Introduction: Time scales for the Quaternary, Isotopes and decay
2. Radiocarbon dating: principles and applications
3. Cosmogenic nuclides: 3He,10Be, 14C, 21Ne, 26Cl, 36Cl
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology and ice cores chronologies
7. Cs-137 and Pb-210 (soil, sediments, ice core)
8. Summary and comparison of results from several dating methods at specific sites

Prerequisites / notice

Visit to radiocarbon lab, cosmogenic nuclide lab, accelerator (AMS) facility.

Visit to Limno Lab and sampling a sediment core

Optional (individual): 1-5 days hands-on radiocarbon dating at the C14 lab at ETH Hoenggerebrg.

Required: attending the lecture, visiting laboratories, handling back solutions for problem sets (Exercises)

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
Overview of the most important earth surface processes and landforms in cold regions (regions with glaciers and intense frost) with emphasis on high-mountain aspects. Discussion of present research challenges.

Objective
Knowledge of the most prominent climate-related geomorphological processes and phenomena in high-mountain regions, understanding of primary research challenges.

Content
Erosion and sedimentation by glaciers as a function of topography, englacial temperature, sediment balance, sliding and melt water runoff.
Processes and landforms in regions of seasonal and perennial frost (frost weathering, rock falls, debris cones/talus, solifluction, permafrost creep/rock glaciers, debris flows).

Lecture notes
Glacial and periglacial geomorphodynamics in high-mountain regions. Ca. 100 pages.

Literature
references in skript

Prerequisites / notice
Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes

Remote Sensing
The courses of this module are offered by UZH and must be registered at UZH.

Remote Sensing: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4263-00L</td>
<td>Remote Sensing and Geographic Information Science V (University of Zürich)</td>
<td>W</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
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<tr>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: GEO371</td>
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Remote Sensing: Courses of Choice

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>651-4269-00L</td>
<td>Specialisation in Remote Sensing: Spectroscopy of the Earth System (University of Zurich)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td></td>
<td>UZH Module Code: GEO442</td>
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<td></td>
<td>Prerequisite: Remote Sensing Methods (UZH Module Code: GEO371)</td>
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<td>6 credits</td>
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<td>University lecturers</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<td>UZH Module Code: GEO443</td>
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<td>Prerequisite: Remote Sensing Methods (UZH Module Code: GEO371)</td>
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<td>Mind the enrolment deadlines at UZH:</td>
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<td><a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
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Shallow Earth Geophysics
Courses are only offered in spring semester.

Modules from the Engineering Geology Major
Choice from Engineering Geology Required Modules

Modules from the Geophysics Major
Choice from Geophysics Compulsory Modules
Choice from Geophysics Restricted Choice Modules

Modules from the Mineralogy and Geochemistry Major
Choice from the Mineralogy and Geochemistry Restricted Choice Modules

Modules from the Major Geology Restricted Choice Modules
Choice from the Geology Restricted Choice Modules

Major in Engineering Geology
Compulsory Modules Engineering Geology
Engineering Geology: Fundamentals
Abstract
This course focuses on the principles (fundamentals) and basic concepts of rock mechanics and rock engineering (e.g. tunnelling, rock slope stability).

Objective
The course aims to introduce the fundamentals and basic concepts of rock mechanics and generic rock engineering. The student shall understand how rocks behave at different scales, under various artificial loads and in the shallow subsurface (a few km below ground). The link between rock mechanics, geology, hydrogeology and tectonics (i.e. the conditions under which the rock formed) will be clearly established. The student shall understand basic principles of rock mechanics and rock engineering. In addition, the student shall learn how to apply the results from lab and field investigations to simple engineering problems. This knowledge is required for subsequent integration courses (Landslide Analysis and Hazard Mitigation; Engineering Geology of Underground Excavations).

Content
This course focuses on the principles (fundamentals) and basic concepts of rock mechanics and generic rock engineering. The course is compulsory for the MSc Eng Geol. The applications of rock mechanical principles and rock engineering methods are extensively covered in subsequent courses.

Lecture notes
Written course documentation available on our homepage: https://www.ethz.ch/content/specialinterest/erdw/geological-institute/engineering-geology/en/teaching/msc/fall/rock_mechanics.html

Abstract
The course presents the principles of soil mechanics and soil behaviour characteristics and its applications in geotechnical structures and systems. It is based on more descriptive courses on Engineering Geology within the BSc Geol. Program and is a compulsory prerequisite for other courses within the MSc Eng. Geol. program.

Objective
Understanding the principles of soil behaviour and the fundamentals of geotechnical practices in soils.

Ability to communicate with geotechnical engineers.

Content
Soil Mechanics:
Fundamental concepts of strength and deformation of different soils. Introduction to geotechnical calculations
Significance of (ground)water
Geotechnical Engineering in Soils:
Evaluation of geotechnical scenarios, handling of forecast uncertainties, relation of soil properties and soil composition, interactions between soil and building,
standard construction methods in soils (foundations, slopes, dams and levees), requirements for the geotechnical prognosis

Lecture notes
This lecture is supported by the textbook: "Geotechnical Engineering" by Donald P. Coduto, 2nd edition, 2011; ISBN-13: 978-0-13-135425-8

Prerequisites / notice
Courses must be completed:
Introduction to Engineering Geology (BSc level)
Introduction to Groundwater
Sedimentology and Quaternary deposits
Principles of Physics

Courses recommended:
Eng Geol Site Investigations
Eng Geol Field Course I (soils)
Clay Mineralogy

Abstract
The course provides an introduction into quantitative analysis of groundwater flow and solute transport. It is focused on understanding, formulating, and solving groundwater flow and solute transport problems.

Objective
a) Students understand the basic concepts of groundwater flow and solute transport processes, and boundary conditions.

b) Students are able to formulate simple, practical groundwater flow and solute transport problems.

c) Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems.

1. Introduction to groundwater problems. Concepts to quantify properties of aquifers.

2. Flow equation. The generalised Darcy law.

3. The water balance equation and basic concepts of poroelasticity.


5. Analytical solutions to flow problems

6. Finite difference scheme solution for simple flow problems.


10. Analytical solutions to transport problems.

11. Fractured and karst aquifers.

12. The unsaturated zone and capillary pressure.

13. Examples of applied hydrogeology from Switzerland and around the world. (Given by Dr. Beatrice Marti from Hydrosolutions Ltd.)

Lecture notes
Handouts of slides.
Engineering Geology: Methods

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<th>Number</th>
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<tr>
<td>651-4065-00L</td>
<td>Geological Site Investigations</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>M. Ziegler</td>
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<td></td>
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<td>This course introduces students to the methods used in characterising, developing or monitoring geotechnical engineering project sites. Measurements, tools and analyses are described that are relevant to determining the geologic conditions at a site as well as deformations that occur under natural or construction conditions.</td>
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<td>This course aims at introducing the general procedures taken during an engineering geological site investigation. Students who complete the course should be able to design a site investigation program of measurements based on information from initial desk studies, and to analyse, integrate and interpret data from the measurement program.</td>
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<td>The methods that are routinely employed in site investigations will be described focusing on their applicability in different geologic environments. The limitations of the data in constraining the parameters of interest will be addressed together with problems of interpretation and cost-versus-information value. Specific topics addressed include drilling, coring, sampling, borehole testing, geophysical methods used in engineering geology, satellite, air- and ground-based surface and displacement monitoring (photogrammetry, LIDAR and Radar), and in-situ deformation measurement methods.</td>
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<td>Lecture notes will be available for download 1-2 days before each class.</td>
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<td>Literature</td>
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Supplemental literature will be suggested and made available during the course.

Rock and Soil Mechanical Lab Practical

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<th>Number</th>
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<tr>
<td>651-4125-00L</td>
<td>Rock and Soil Mechanical Lab Practical</td>
<td>O</td>
<td>3</td>
<td>2P</td>
<td>L. de Palézieux dit Falconnet, O. Moradian</td>
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<td></td>
<td>Abstract</td>
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<td>In this course, students will gain hands on experience performing laboratory and index tests commonly used in Rock and Soil Mechanics. The course is divided into two modules, with half the semester devoted to rock mechanic testing, and half to soil mechanics testing.</td>
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<td>This course introduces the fundamentals of laboratory testing of rock and soil. Students will learn how to interpret laboratory data, the expected accuracy and limitations of common laboratory tests and the most appropriate testing method(s) for a given problem.</td>
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<td>In the Rock Mechanics lab, the following laboratory tests are performed: Ultrasonic velocity measurements, Point load test, Brazilian tensile test, Uniaxial compression test, Triaxial compression test. Through performing these tests, students will get familiar with stress-strain curves, tensile, unconfined, and confined strength of rocks, Young's modulus and Poisson ratio, and finally cohesion and friction angle of intact rocks. In the Soil Mechanics Lab, the following seven laboratory tests are performed: Sieve Analysis, Hydrometer Analysis, Atterberg Limits, Proctor Compaction, Direct Shear Test, Falling Head Permeability and Consolidation Test. Through performing these tests, students gain an understanding of the relationship between index properties and soil behavior, as well as the strength, deformability and hydraulic characteristics of soils.</td>
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Engineering Geology: Integration

Courses for this Module take place in spring semester.

Engineering Geology: Industrial Internship

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<tr>
<td>651-4071-00L</td>
<td>Industrial Internship</td>
<td>O</td>
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<td>external organisers</td>
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<td>Abstract</td>
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<td>The Industrial Internship of the Eng Geol Major takes place in the second MSc year after consultation with Dr. Heike Willenberg. Detailed regulations of this practical are published on the Engineering Geology Website.</td>
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<td>The industry practical is supervised both from the industry partner and ETH and consists of technically and/or scientifically challenging work in the engineering geology domain. The regular duration of the practical is 10 weeks. The practical is pre-defined in a work plan and concluded with a report written by the student.</td>
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Major in Geophysics

Compulsory Modules Geophysics

Geophysics: Methods I

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<th>Number</th>
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651-4005-00L Geophysical Data Processing W+ 3 credits 2G C. V. Cauuzzi, L. Passarelli

Abstract
This course presents fundamental digital signal processing and filter theory with a focus on geophysical applications.

Objective
The goal of the course is to provide an understanding of the principles of digital signal processing and filter theory. Form: two hours lecture with two hours of computer based exercises per week over 7 weeks.

Content
Analog-digital conversion: dynamic range and resolution; Dirac-impulse, step function; Laplace transformation; Z-transformation; Differential equations of linear time-invariant systems; Examples: seismometer and RC-filter; Impulse response and transfer function; Frequency selective filters: example Butterworth filters; Digital filters: impulse invariance and bilinear transformation; Inverse filters; Response spectra.

Lecture notes
Lecture notes will be made available for download from the website of the course.

Literature
The class follows no single book. A list of relevant texts will be given in class.

Prerequisites / notice
Assumed existing knowledge:
(a) time series, discrete systems, Fourier transform, convolution, power spectrum, correlation, stochastic time series (a course dealing with these topics is "Analysis of Time Series in Environmental Physics and Geophysics");
(b) Matlab.

Students must bring their own laptop in class for Matlab exercises.

651-4241-00L Numerical Modelling I and II: Theory and Applications W+ 6 credits 4G T. Gerya

Abstract
In this 13-week sequence, students learn how to write programs from scratch to solve partial differential equations that are useful for Earth science applications. Programming will be done in MATLAB and will use the finite-difference method and marker-in-cell technique. The course will emphasise a hands-on learning approach rather than extensive theory.

Objective
The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.

Content
A provisional week-by-week schedule (subject to change) is as follows:

Week 1: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.


Week 3: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.

Week 4: Solving momentum and continuity equations in case of constant viscosity using pressure-velocity formulation with staggered grid.

Week 5: Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.

Week 6: Solving momentum and continuity equations for the moment equations. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.


Week 8: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.

Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.


GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

Literature

Geophysics: Methods II

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<th>Number</th>
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<tr>
<td>651-4001-00L</td>
<td>Geophysical Fluid Dynamics</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>J. A. R. Noir</td>
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Abstract
Fluid mechanics is one of the fundamental building blocks of modern geophysics. This course aims to provide the students with the basic tools used in fluid dynamics studies of geophysical-astrophysical problems. The course is a combination of lectures, exercises and demo experiments.

Objective
The goal of this course is to introduce you to some fundamental concepts of fluid dynamics, dimensional analysis and scaling laws. A particular attention is given to the assumptions and approximations underlying the derivations of the equations in various situations. The lectures are a mix of table top experiments, everyday observations and theoretical derivations.
The course guides students in learning mathematical machinery used to solve various physical problems. Special attention is paid to:

1) Fundamentals of fluid mechanics.
2) Ideal inviscid fluids.
3) Incompressible viscous fluids.
4) Advanced topics, one of the following:
   - Elements of Thermal convection.
   - Rotating fluids.
   - Stratified fluids.
   - Instabilities and Turbulence.

The slides of last year presentations will be made available at the beginning of the semester, they may be subject to changes during the lectures.

**Literature**

**651-4007-00L**

**Continuum Mechanics**

**Abstract**
In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

**Objective**
The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth's mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.

Content
A provisional week-by-week schedule (subject to change) is as follows:

**Weeks 1, 2:** The continuity equation
- Exercise: Computing the divergence of velocity field.

**Weeks 3, 4:** Density and gravity
- Exercises: Computing density, thermal expansion and compressibility from an equation of state. Derivation of gravitational acceleration and its divergence from gravitational potential.

**Weeks 5, 6:** Stress and strain
- Exercises: Analysing strain rate tensor for solid body rotation. Computing stress invariants

**Weeks 7, 8:** The momentum equation
- Exercises: Deriving momentum equation. Computing velocity for magma flow in a channel.

**Week 9:** Viscous rheology of rocks
- Theory: Solid-state creep of minerals and rocks as the major mechanism of deformation of the Earth’s interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws.
- Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

**Weeks 10, 11:** The heat conservation equation

**Week 12, 13:** Elasticity and plasticity
- Exercise: Compute viscoelastic stress evolution.

**Week 14:** Fluid flow in deforming porous media. Darcy equation for fluid percolation. Derivation of Darcy equation from Stokes equation for channel flow. Dependence of permeability on porosity and grain size. Coupled hydro-mechanical momentum and continuity equations for solid matrix and percolating fluid. Fluid and solid Lagrangian reference frames.

**Lecture notes**
GRADING will be based on homeworks (1/3) and oral exam (2/3).

**Literature**

**651-4130-00L**

**Mathematical Methods**

**Abstract**
The course guides students in learning mathematical machinery used to solve various physical problems. Special attention is paid to the analytical methods to solve partial differential equations describing physical processes such as heat transfer, electromagnetic induction, wave propagation, among others.

**Objective**
The goal of this course is to refresh and deepen students’ knowledge in mathematical methods relevant to the problems arising in solid Earth physics.

**Content**
The provisional subjects covered in this course are as follows:

(i) Vector calculus, vector identities, Parametric Curves and Surfaces
(ii) Calculus in curvilinear coordinates. Spherical and Cylindrical bases
(iii) Partial Differential Equations, Laplace equation, Helmholtz equation, Separation of variables, eigenvalues and eigenfunctions, spherical harmonic analysis
(iv) Special functions: Delta function, Heaviside function, Bessel functions, Green's functions
(v) Tensors, Einstein notation, tensor algebra

Note: the actual content of the course may have slight deviations from the stated list.

**Lecture notes**
Current lecture notes and homeworks will be found during the course at www.polybox.ethz.ch
Lecturers

In the course it is explained how the disciplines of seismology, geology, strong-motion geophysics, and earthquake engineering contribute.

ECTS

The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required.

T. Diehl

1. E. Kreyszig, "Advanced engineering mathematics"
2. M. Boas, "Mathematical methods in the physical science"
4. R. Sneider, "A guided tour of mathematical methods for the physical sciences"

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Seismology

Number | Title | Type | ECTS | Hours | Lecturers
651-4014-00L | Seismic Waves II | W+ | 3 credits | 2G | T. Diehl. F. Lanza, A. Obermann

Abstract

This course provides an overview on the most widely used seismological methods to image the Earth's interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

Objective

Understand the strengths and weaknesses of various active and passive tomographic methods to image the structure of the Earth.

Literature


651-4015-00L | Earthquakes I: Seismotectonics | W+ | 3 credits | 2G | A. P. Rinaldi, T. Diehl

Abstract

If you're interested in knowing more about the relationship between seismology and plate tectonics, this is the course for you. (If you're not that interested, but your program of study requires that you complete this course, this is also the course for you.)

Objective

The aim of the course is to obtain a basic understanding of the physical process behind earthquakes and their basic mathematical description. By the conclusion of this course, we hope that you will be able to:
- describe the relationship between earthquakes and plate tectonics in a more sophisticated and complete way
- explain earthquake source representations of varying complexity
- address earthquakes in the context of different tectonic settings
- explain the statistical behaviour of global earthquakes
- describe and connect the ingredients for a seismotectonic study

Content

The course features a series of 14 meetings, in which we review some fundamentals of continuum mechanics and tensor analysis required for a complete understanding of the relation between earthquakes and plate tectonics. Our goal is to help you understand deformation the small scale (fault) to the scale of plate tectonics. We will tell you about several ways to represent an earthquake source; we'll present these in order of increasing sophistication. You will enjoy (at least) a computer/class exercise and a guest lecture.

Topics covered in the course include:
- review of stress and deformation in the Earth, stress and strain tensors, rheology and failure criteria, fault stresses, friction and effects of fluids
- earthquake focal mechanisms; relationship between stress fields and focal mechanisms; seismic moment and moment tensors;
- crustal deformation from seismic, geologic, and geodetic observations;
- earthquake stress drop, scaling, and source parameters;
- global earthquake distribution; current global earthquake activity;
- different seismotectonic regions; examples of earthquake activity in different tectonic settings.

Lecture notes

Course notes will be made available on a designated course web site. Most of the topics discussed in the course are available in the book mentioned below.

Literature


Basic knowledge of continuum mechanics and rock mechanics, as well as notion of tensor analysis is strongly suggested. We recommend to have taken the course Continuum Mechanics (generally taught during the Fall semester).

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.

651-4021-00L | Engineering Seismology | W+ | 3 credits | 2G | D. Fäh, V. Pernon

Abstract

This course is a general introduction to the methods of seismic hazard analysis. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties.

Objective

This course is a general introduction to the methods of seismic hazard analysis.

Content

In the course it is explained how the disciplines of seismology, geology, strong-motion geophysics, and earthquake engineering contribute to the evaluation of seismic hazard. It provides an overview of the input data and the tools in deterministic and probabilistic seismic hazard assessment, and discusses the related uncertainties. The course includes the discussion related to Intensity and macroseismic scales, historical seismicity and earthquake catalogues, ground motion parameters used in earthquake engineering, definitions of the seismic source, ground motion attenuation, site effects and microzonation, and the use of numerical tools to estimate ground motion parameters, both in a deterministic and probabilistic sense.

During the course recent earthquakes and their impacts are discussed and related to existing hazard assessments for the areas of interest.

Physics of the Earth's Interior

Number | Title | Type | ECTS | Hours | Lecturers
651-4010-00L | Planetary Physics and Chemistry | W+ | 3 credits | 2G | P. Tackley

This course will be taught in fall 2017 and it will be followed by Earthquakes 2: Source Physics in Spring 2018.

The course will be evaluated in a final written test covering the topics discussed during the lectures.

The course will be worth 3 credit points, and a satisfactory total grade (4 or better) is needed to obtain 3 ECTS.

The course will be given in English.
Abstract
This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system and also apply it to ongoing discoveries regarding planets around other stars.

Objective
The goal of this course is to enable students to understand current knowledge and uncertainties regarding the formation, structure, dynamics and evolution of planets and moons in our solar system, as well as ongoing discoveries regarding planets around other stars. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.

Lecture notes
Slides and scripts will be posted on Moodle.

Literature
It is recommended but not mandatory to buy one of these books:

►►► Applied Geophysics

►►►► Applied Geophysics: Compulsory Courses
The compulsory courses take place in spring semester.

►►►► Applied Geophysics: Courses of Choice
The compulsory courses take place in spring semester.

►► Major in Mineralogy and Geochemistry

►► Compulsory Module in Analytical Methods in Earth Sciences
Students have to complete 6 credits in part A (microscopy courses), and 6 credits in part B (methods).

►►► Microscopy Courses
Compulsory Module in Analytical Methods in Earth Sciences: Microscopy Courses

►►► Analytical Methods Courses
Compulsory Module in Analytical Methods in Earth Sciences: Analytical Methods Courses

►► Restricted Choice Modules Mineralogy and Geochemistry
A minimum of two restricted choice modules must be completed in the major Mineralogy and Geochemistry.

►►► Mineralogy and Petrology

►►►► Mineralogy and Petrology: Compulsory Courses

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<tr>
<td>651-4028-00L</td>
<td>Physical Properties of Minerals</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Petitgirard, G. Spiekermann</td>
</tr>
</tbody>
</table>

Abstract
Physical properties of minerals, e.g. electrical properties, elasticstical properties are discussed. The effect of the crystal symmetry on the symmetry of physical properties as well as the mathematical formulation of the physical properties are major topics.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4039-00L</td>
<td>Thermodynamics Applied to Earth Materials</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>J. Connolly</td>
</tr>
</tbody>
</table>

Abstract
This course develops the thermodynamic concepts necessary to predict phase equilibria and to compute physical properties from thermodynamic data.

Objective
To provide students with the conceptual and practical skills necessary to implement thermodynamic models and data as provided in the earth science literature. The computer software package Maple is relied upon to allow students to solve realistic problems without the distraction of mathematical details.

Content
Elementary concepts (1st and 2nd Laws; composition, state and extent); stability criteria; Legendre transforms; Maxwell relations and other manipulations of thermodynamic functions; calculation of Gibbs energy for a pure solid; simple solution models; order-disorder solution models; reciprocal solution models; equations of state for molecular fluids; free energy minimization.

This course is neither an introduction to computer methods for calculating petrological phase equilibria nor an introduction to phase diagram methods.

Prerequisites / notice
The grade for the course is based on exercises assigned as homework.

Some familiarity with elementary thermodynamics (phase rule, reactions) and mathematics (differentiation, integration) is assumed. Experience with Maple or comparable programs such as Mathematica is helpful.

►►►►► Mineralogy and Petrology: Courses of Choice

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4063-00L</td>
<td>X-Ray Powder Diffraction</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
</tbody>
</table>

Abstract
In the course the students learn to measure X-ray diffraction patterns of minerals and to evaluate these using different software for qualitative and quantitative mineral composition as well as crystallographic parameters.

Objective
Upon successful completion of this course students are able to:
- describe the principle of X-ray diffraction analysis
- carry out a qualitative and quantitative mineralogical analysis independently,
- critically assess the data,
- communicate the results in a scientific report.

Content
Fundamental principles of X-ray diffraction Setup and operation of X-ray diffractometers Interpretation of powder diffraction data Qualitative and quantitative phase analysis of crystalline powders (e.g. with Rietveld analysis)

Lecture notes
Selected handouts will be made available in the lecture
Students will learn to understand the use of non-metallic mineral resources from a geological and mineralogical point of view as well as economic, strategic and environmental aspects are discussed. Examples from all over the world with a specific focus on the non-mineral mineral resources potential in Switzerland.

Upon successful completion of this course students are able to:

- critically assess the data,
- carry out a qualitative and quantitative mineralogical analysis independently,
- describe the principle of X-ray diffraction analysis
- evaluate the data,
- communicate the results in a scientific report.

Course "Applied mineralogy and non-metallic resources II" (fall/summer semester):


Chapter 1: Petrology and Volcanology  
Chapter 2: Applied Mineralogy and Non-Metallic Resources I  
Chapter 3: Applied Mineralogy and Non-Metallic Resources II  
Chapter 4: Petrology and Volcanology: Compulsory Courses  
Chapter 5: Petrology and Volcanology: Courses of Choice

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Mineral Resources

Mineral Resources: Compulsory Courses

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<thead>
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</thead>
<tbody>
<tr>
<td>651-4097-00L</td>
<td>Applied Mineralogy and Non-Metallic Resources I</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>R. Kündig</td>
</tr>
</tbody>
</table>

Geological and mineralogical aspects to important non-metallic mineral resources. Industrial use of specific mineral resources as well as economic, strategic and environmental aspects are discussed. Examples from all over the world with a specific focus on the non-mineral mineral resources potential in Switzerland.

Objective

Students will learn to understand the use of non-metallic mineral resources from a geological and mineralogical point of view as well as from industrial, technical and strategic (political) point of view. Environmental aspects on the worldwide use of non-metallic mineral resources are discussed. A special focus will be given on the situation in Switzerland.

Content

Teaching, case-studies and excursions (e.g. raw-material industry).

Course "Applied mineralogy and non-metallic resources I" (autumn/winter semester):
Non-metallic resources. Occurrences, geology, extraction, properties, fabrication and use. Industrial aspects, (new) technologies, market, stock, situation, reserves & resources, trends and development, environmental aspects, law.

Chapters: e.g. coal/carbon (coal, graphite, diamond, fullerens); oil/gas (oil- and tarsands, oil-shists); phosphates/nitrates; aluminum (bauxite, corundum); salt; carbonates; titanium; clay and clay minerals; sulphur; gypsum/anhydrite; fluorite; asbestos; talc; micas; rare earth elements.

Course "Applied mineralogy and non-metallic resources II" (fall/summer semester):

Chapters: e.g. Stone industry - technical aspects of building stones, properties, weathering, treatment, quarries, products. Crushed stones - quarries, products, planning, environment. Gravel an sand - resources/reserves, environment (protection/law), alternative products (substitution). Cement and concrete (geological resources, prospection, fabrication, environment).

Lecture notes

Notes handed out during lectures

651-4037-00L

Mineral Resources I

Can be chosen as an elective course within the Bachelor. Prospective MSC-Students attending the module "Mineral Resources I and II" should attend Mineral Resources I and II in the first year of their MSC studies.

Abstract

Principles of hydrothermal ore formation, using base metal deposits (Cu, Pb, Zn) in sedimentary basins to explain the interplay of geological, chemical and physical factors from global scale to sample scale. Introduction to orthomagmatic ore formation (mostly Cr, Ni, PGE). Introduction to supergene residual deposits (Ni, Al).

Objective

Understanding the fundamental processes of hydrothermal, magmatic and supergene ore formation, recognising and interpreting mineralised rocks in geological context.

Content

(a) Principles of hydrothermal ore formation: base metal deposits in sedimentary basins. Practical classification of sample suites by genetic ore deposit types

Mineral solubility and ore deposition, principles & thermodynamic prediction using activity diagrams. Driving forces and structural focussing of hydrothermal fluid flow

(b) Introduction to orthomagmatic ore formation. Chromite, Ni-Cu sulphides and PGE in layered mafic intrusions. Distribution coefficients between silicate and sulphide melts. Carbonatites and pegmatite deposits.

(c) Introduction to supergene residual deposits with emphasis on Ni laterites and bauxites

Lecture notes

Notes handed out during lectures

Prerequisites / notice

2 contact hours per lecture / week including lectures, exercises and practical study of samples, and small literature-based student presentations. Supplementary contact for sample practicals and exercises as required. Credits and mark based on participation in course (exercises, 50%) and 1h30 written exam in the last lecture of the semester (50%).

Handouts with extensive list of primary literature available.

Introduction to computer tools for the simulation of hydrothermal processes: HYDROTHERM for fluid flow simulations, Geochemist's Workbench for thermodynamic modeling. While learning the respective computer programs is an essential part of the course, the emphasis works.

No programming knowledge is necessary.

Virtual machine or team up with a colleague with a Window computer.

Resources and their valuation. Teams are formed as Limited Partnership companies that have to select and bid for a mineral property offered during an auction. Each company has the same nominal budget. The highest bidder purchases the selected property, to be announced.

Global mineral economics and the strategies of mineral exploration -- including geological, geochemical and geophysical methods, but also non-geological factors such as organisational, political and environmental aspects. Changing external lecturers.

Restricted participation with priority for MSc Earth Science students taking the Module 'Mineral Resources and Applied Mineralogy'. Interested ETH students please register through myStudies by second semester week.

Global mineral economics and the strategies of mineral exploration -- including geological, geochemical and geophysical methods, but also non-geological factors such as organisational, political and environmental aspects. Changing external lecturers.

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Global mineral economics and the strategies of mineral exploration -- including geological, geochemical and geophysical methods, but also non-geological factors such as organisational, political and environmental aspects. Changing external lecturers.
Prerequisites / notice
Prerequisites: Knowledge of mineral deposit-type characteristics is useful (orogenic gold, Cu-Zn VMS, Ni-Cu-PGE); at least "Integrierte Erdsysteme", "Ore Deposit 1", or adequate knowledge of mineral deposits acquired by preparatory reading. Basic knowledge of ArcGIS software is important to produce maps and sections required in reports. Training exercises and tutorials will be provided in advance to prepare for the course. Taught biennially in collaboration with University of Geneva.

Taught competencies
This course is co-organised by ETH Zurich (Prof. C. Chelle-Michou) and University of Geneva (Prof. R. Moritz)

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

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

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

Geochemistry

Geochemistry: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4049-00L</td>
<td>Conceptual and Quantitative Methods in Geochemistry</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>O. Bachmann, G. De Souza, B. J. Peters</td>
</tr>
<tr>
<td></td>
<td>Prerequisite: Successful completion of the BSc-course &quot;Geochemistry&quot; (651-3400-00L).</td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>This course will introduce some of the main quantitative methods available for the quantitative treatment of geochemical data, as well as the main modelling tools. Emphasis will both be on conceptual understanding of these methods as well as on their practical application, using key software packages to analyse real geochemical datasets.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Development of a basic knowledge and understanding of the main tools available for the quantitative analysis of geochemical data.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>The following approaches will be discussed in detail: major and trace element modelling of magmas, with application to igneous systems; methods and statistics for calculation of isochrons and model ages; reservoir dynamics and one-dimensional modelling of ocean chemistry; modelling speciation in aqueous (hydrothermal, fresh water sea water) fluids. We will discuss how these methods are applied in a range of Earth Science fields, from cosmochemistry, through mantle and crustal geochemistry, volcanology and igneous petrology, to chemical oceanography. A special emphasis will be put on dealing with geochemical problems through modeling. Where relevant, software packages will be introduced and applied to real geochemical data.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Slides of lectures will be available.</td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
<td></td>
<td></td>
<td></td>
<td>Pre-requisite: Geochemie I and II</td>
</tr>
<tr>
<td>651-4227-00L</td>
<td>Planetary Geochemistry</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Schönächler, H. Busemann, A. Hunt</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>To understand the formation and evolution of the solar system and its planets from a geochemical perspective</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The Sun and solid objects in the solar system (planets, comets, asteroids, meteorites, interplanetary dust) are discussed from a geochemical perspective. What does their present-day composition tell us about the origin, formation and evolution of the solar system? The lectures introduce the basics of the terrestrial and giant planets, comets and asteroids, gained from modern space missions and the study of extraterrestrial materials. The chemical and isotopic composition of meteorites, being the most primitive material available for study, is a further major topic.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
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<td></td>
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<td>Slides and additional materials are available electronically</td>
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</tbody>
</table>

Geochemistry: Courses of Choice

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>651-4233-00L</td>
<td>Geotectonic Environments and Deep Global Cycles</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>M. W. Schmidt, P. Ulmer</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>This course addresses master students interested in integral view of processes operating in various tectonic environments, most specifically divergent and convergent plate margins</td>
</tr>
<tr>
<td>651-4057-00L</td>
<td>Climate History and Palaeoclimatology</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida, H. Zhang</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Climate history and palaeoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.</td>
</tr>
</tbody>
</table>

This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system. The purpose of this lecture is to provide a comprehensive overview of: a) the different radiometric methods in Geology, the different dating techniques, the different rock types and the different dating systems. The student will be able to describe the natural factors that lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

### 651-4225-00L Topics in Geochemistry

**Objective**

The course will give students an overview of methods and applications of geochronology across a wide range of Earth Science disciplines. Several in situ methods are used to determine the age of materials and to constrain the rates of geological processes. Students will learn how to analyze geochronological data using the SPSS software package and to interpret results in the context of geological processes. The main topics covered are: Orbital dynamics and Tides, Solar heating and Energy transport, Planetary atmospheres, Planetary surfaces, Planetary interiors, Asteroids and Meteorites, Comets, Planetary rings, Magnetic fields and Magnetospheres, The Sun and Stars, Planetary formation, Exoplanets and Exobiology. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.

**Content**

1. Introduction and overview. Data visualization and statistics in IsoplotR, Principles of U-Pb geochronology
2. In situ U-Pb geochronology 1 (LA-ICPMS/SIMS principles, zircon)
3. In situ U-Pb geochronology 2 (calcite, garnet, other minerals)
4. High-precision ID-TIMS U-Pb geochronology (principles and applications)
5. High-precision U-series geochronology (carbonates, silicates)
6. In situ U-series geochronology (zircon, garnet etc.)
7. K-Ar and 40Ar/39Ar geochronology, Principles and Applications
8. Fission Track dating
9. U-Th/He dating
10. Thermochronology applications/lab visit
11. Noble gases - basics, reservoirs, geo/cosmochem. applications: mainly chronology
12. Cosmogenic nuclides (stable and radionuclides) - basics, geo/cosmochem. applications, C14

**Lecture notes**

Script (for part of the lecture), partly power point presentations (in the web)

### 651-4010-00L Planetary Physics and Chemistry

**Objective**

This course aims to give a physical understanding of the formation, structure, dynamics and evolution of planetary bodies in our solar system and also apply it to ongoing discoveries regarding planets around other stars. The goal of this course is to enable students to understand current knowledge and uncertainties regarding the formation, structure, dynamics and evolution of planets and moons in our solar system, as well as ongoing discoveries regarding planets around other stars. Students will practice making quantitative calculations relevant to various aspects of these topics through weekly homeworks.

**Content**

1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclical variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems? Will mean climate change El Nino frequency and intensity? What factors drive change in mid and high-latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturing Circulation to collapse? When and why has this happened before?

**Literature**

Will be identified based on the chosen topic.

### 651-4229-00L Advanced Geochronology

**Objective**

The purpose of this lecture is to provide a comprehensive overview of: a) the different radiometric methods in Geology, the different dating techniques, the different rock types and the different dating systems. The student will be able to describe the natural factors that lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

**Content**

1. Introduction and overview. Data visualization and statistics in IsoplotR, Principles of U-Pb geochronology
2. In situ U-Pb geochronology 1 (LA-ICPMS/SIMS principles, zircon)
3. In situ U-Pb geochronology 2 (calcite, garnet, other minerals)
4. High-precision ID-TIMS U-Pb geochronology (principles and applications)
5. High-precision U-series geochronology (carbonates, silicates)
6. In situ U-series geochronology (zircon, garnet etc.)
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8. Fission Track dating
9. U-Th/He dating
10. Thermochronology applications/lab visit
11. Noble gases - basics, reservoirs, geo/cosmochem. applications: mainly chronology
12. Cosmogenic nuclides (stable and radionuclides) - basics, geo/cosmochem. applications, C14

**Lecture notes**

Script (for part of the lecture), partly power point presentations (in the web)
Open Choice Modules Mineralogy and Geochemistry

Electron Microprobe Course 1 - Theory

Abstract
Theory on scanning electron microscope (SEM) and on electron microprobe analysis (EPMA) applied to geological materials. Complete presentation of the instrument, interaction of electron with matter, principles of electron imaging (SE, BSE and CL), of electron backscatter diffraction (EBSD), and of X-ray analysis for the chemical characterisation of solid material at the micron-scale.

Objective
Understand how the instrument works, why it is used, and how the different signals are being generated and analysed. Ability to treat and interpret data and to present analytical results, such as calculating a mineral formula from a mineral analysis.

Lecture notes
Script will be provided. [HIGHLY recommended]

Prerequisites / notice
The Theory course is a prerequisite for 651-0048-00L Electron Microprobe Course 2 - Practice

Taught competencies

651-0048-00L Electron Microprobe Course 2 - Practice

Abstract

Objective
Ability to operate the Electron Microprobe with minimal assistance, optimise the analysis setup in order to obtain excellent results, identify possible source of error (troubleshooting) and fix them, data treatment (and interpretation).

Content
Physical principles of electron optics, interaction of electrons with matter, production of X-rays, interaction of X-rays with matter. Detection and analysis. The course includes some live demonstrations on the instrument (remotely).

Lecture notes
Script and User Manual will be provided.
Analytical Competencies
Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to


K. Kunze

Cooperation and Teamwork

2V+2U

Functional principles and operation modes of a scanning electron microscope. Methods and application fields for

W

assessed

Overview of the most common experimental methods employed in petrology to determine thermodynamic and physical properties and

W

, P. A. Sossi, R. Erni, S. Gerstl,

assessed


assessed

Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical

W

3V

A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods
designed to use these probes in the structural and chemical analysis of various materials.

3 credits

Domain A - Subject-specific Competencies

Techniques and Technologies

assessed

Domain B - Method-specific Competencies

Analytical Competencies

assessed

Decision-making

assessed

Problem-solving

assessed

Project Management

assessed

Domain C - Social Competencies

Cooperation and Teamwork

assessed

Domain D - Personal Competencies

Creative Thinking

assessed

Critical Thinking

assessed

651-1851-00L Introduction to Scanning Electron Microscopy

W

1 credit

2G

Does not take place this semester. Course is replaced by 651-0046-00, it will no longer take place.

Introduction to Scanning Electron Microscopy and Microanalysis including Practical training.

Introduction in scanning electron microscopy and microanalysis. Obtain practical experience in operating a SEM.

Functional principles and operation modes of a scanning electron microscope. Methods and application fields for

- imaging (SE, BSE, FSE, AE, CL).

- X-ray spectroscopy (EDX)

- Electron diffraction (EBSD, Channeling, Orientation Imaging).

Methods for sample preparation

Practical exercises.

Scripts and operation manuals are provided during the course.


Full day block course after the end of HS

Literature


327-0703-00L Electron Microscopy in Material Science

W

4 credits

2V+2U


A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods
designed to use these probes in the structural and chemical analysis of various materials.

A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods
designed to use these probes in the structural and chemical analysis of various materials.

This course provides a general introduction into electron microscopy of organic and inorganic materials. In the first part, the basics of

transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen

preparation, imaging and image processing. In the third part, recent applications in materials science, solid state physics, structural biology,

structural geology and structural chemistry will be reported.

will be distributed in English


651-3541-00L Exploration and Environmental Geophysics

W

4 credits

3V

P. Edme, H. Maurer, A. Shakas

Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical

and electromagnetic methods, Refraction and reflection seismics, Georadar. Discussion of survey design, sources and receivers and data

processing.

Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to

exploration and environmental geophysics in soil, ice and lithosphere at different scales. Getting familiar with measuring- and interpretation

procedures. Pointing out the possibilities and limitations of geophysical methods.

Basics of Geophysical Methods: Potential field methods (Gravimetrics and Magnetics), Electrical and electromagnetic methods, Refraction

and reflection seismics, Georadar. Important geophysical (subsurface) Parameters. Operating procedures for sources and receivers.

Principles of digital Signal Recording. Explanation of various steps of Digital Signal Processing. Outlook on advanced methods and

interpretation procedures. Examples of specific problems, like landfills and rockslides. There will also be demonstrations in the Field.

Available through eDoz/ILIAS.

Additional material will be provided by the lecturers.


651-4086-00L Experimental Methods in Petrology

W

3 credits

2P

C. Liebske, P. A. Sossi

Overview of the most common experimental methods employed in petrology to determine thermodynamic and physical properties and

phase equilibria of minerals, mineral assemblages, magmas and fluids. The basic principals of low, moderate, high and ultrahigh pressure
devices are discussed combined with an introduction into the synthesis of starting materials and the evaluation of run products.

651-3541-00L Exploration and Environmental Geophysics

W

4 credits

3V

P. Edme, H. Maurer, A. Shakas

Overview and understanding of the most important geophysical methods: Potential field methods (Gravimetrics and Magnetics), Electrical

and electromagnetic methods, Refraction and reflection seismics, Georadar. Discussion of survey design, sources and receivers and data

processing.

Overview and understanding of the most important geophysical methods. Proposed solutions to assess and observe problems relevant to

exploration and environmental geophysics in soil, ice and lithosphere at different scales. Getting familiar with measuring- and interpretation

procedures. Pointing out the possibilities and limitations of geophysical methods.

Basics of Geophysical Methods: Potential field methods (Gravimetrics and Magnetics), Electrical and electromagnetic methods, Refraction

and reflection seismics, Georadar. Important geophysical (subsurface) Parameters. Operating procedures for sources and receivers.

Principles of digital Signal Recording. Explanation of various steps of Digital Signal Processing. Outlook on advanced methods and

interpretation procedures. Examples of specific problems, like landfills and rockslides. There will also be demonstrations in the Field.

Available through eDoz/ILIAS.

Additional material will be provided by the lecturers.


This course shall provide the basics of experimental petrology. The principal goals are the acquisition of basic knowledge about experimental equipment employed in petrology and the design and setup of an experimental study targeted to obtain quantitative data on phase relations, thermodynamic, kinetic and rheologic properties of earth materials as well as the examination, analysis and evaluation of experiments. At the end of the course, the participants should be able to evaluate experimental data independently and design appropriate experiments on their own.

The practical work in the laboratories are conducted (with the exception of exercise #1) on a small research project where the various techniques and equipment are demonstrated and the practical use is trained.

A summary of the material presented in the lectures are distributed weekly.

Currently, there is no comprehensive book available that summarizes the most important aspects of experimental petrology; publications related to individual subjects are referred during the lectures.

This course addresses to a public (master and PhD students) that is interested in an introduction to experimental research in petrology, but does not require basic knowledge in experimental methods. However, basic knowledge in petrology and physical chemistry (thermodynamics) is required to follow the course.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A summary of the material presented in the lectures are distributed weekly.</td>
<td>This course addresses to a public (master and PhD students) that is interested in an introduction to experimental research in petrology, but does not require basic knowledge in experimental methods. However, basic knowledge in petrology and physical chemistry (thermodynamics) is required to follow the course.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>651-4114-00L</th>
<th>Illustrations in Natural History (University of Zürich)</th>
<th>W</th>
<th>1 credit</th>
<th>1V</th>
<th>University lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>We offer the opportunity to develop drawing skills which can be applied for scientific studies and publications. We emphasise the reproduction of natural objects with and without interpretations. Technical and 3D-drawings as well as descriptive geometry are not dealt with in this course.</td>
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<tr>
<td>Content</td>
<td>In this course, both classic and computer-based drawing and illustration-techniques are presented. We begin with sketches with the pencil and continue with Indian ink which we use for drawings using hatchings and dots. Finally, one drawing is carried out in detail with a pencil. This drawing will then be scanned and processed in Photoshop. The emphasis is on practicing the methods.</td>
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<tr>
<td>Lecture notes</td>
<td>- not mandatory!</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Please bring pencils (HB and 2H) as well as Indian ink-pens or fine black markers. In the second half of the semester, the students may bring their own laptops with Photoshop because usually, we do not have enough computers in the lecture hall for all.</td>
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<table>
<thead>
<tr>
<th>651-4273-00L</th>
<th>Numerical Modelling in Fortran (Project)</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>P. Tackley</th>
</tr>
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<tbody>
<tr>
<td>Objective</td>
<td>Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.</td>
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<tr>
<td>Content</td>
<td>The project consists of writing a Fortran program to solve a problem agreed upon between the instructor and student; the topic is often related to (and helps to advance) the student's Masters or PhD research. The project is typically started towards the end of the main Fortran class when the student has acquired sufficient programming skills, and is due by the end of Semesterprüfung week.</td>
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<tr>
<td>Lecture notes</td>
<td>See <a href="http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html">http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html</a></td>
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<thead>
<tr>
<th>651-1392-00L</th>
<th>Palaeontological Colloquium (University of Zurich)</th>
<th>E-</th>
<th>0 credits</th>
<th>1K</th>
<th>University lecturers</th>
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</thead>
<tbody>
<tr>
<td>Objective</td>
<td>The course 'Experimental methods in petrology' covers the following subjects:</td>
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<tr>
<td>Content</td>
<td>(1) Introduction and historical summary of experimental petrology</td>
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<td></td>
<td>(2) Experimental methods at ambient pressure (1 bar) with practical exercise to determine the free energy of formation of wustite (FeO)</td>
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<td>(3) Experimental buffering techniques (phase rule, buffering of partial pressures of gases and supercritical fluids, buffering of mixed volatile phases at elevated pressures, buffering of activities and solid-solid solutions in solid phases</td>
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<td></td>
<td>(4) Experimental methods at moderate pressures: externally (cold seal) and internally (IHPV) heated gas-pressure apparatus with practical demonstration/exercise</td>
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<td>(5) High-pressure solid-media experimental techniques (piston cylinders)</td>
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<td></td>
<td>(6) Ultrahigh-pressure experimental techniques (multi-anvil apparatus, diamond-anvil-cells (DAC)</td>
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<td></td>
<td>(7) Evaluation of petrologic experiments (preparation of run products, analytical and spectroscopic methods of examination and quantification)</td>
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<tr>
<td>Prerequisites / notice</td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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</tbody>
</table>
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work. The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulic. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).
### Module Code: GEO122

**Mind the enrolment deadlines at UZH:**
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

<table>
<thead>
<tr>
<th>Course</th>
<th>Objective</th>
<th>Content</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2601-00L</td>
<td><strong>Human Geography I: One Earth - Many Worlds</strong> (University of Zurich)</td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline.html">https://www.uzh.ch/cmsssl/en/studies/application/deadline.html</a></td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO112</td>
<td>Imparting of research questions and basic principles in Human Geography</td>
<td>To get an overview about basic research questions and principles of Human Geography</td>
<td>Imparting of research questions and basic principles in Human Geography</td>
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<tr>
<td>651-4088-03L</td>
<td><strong>Physical Geography III (Geomorphology and Glaciology)</strong> (University of Zurich)</td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline.html">https://www.uzh.ch/cmsssl/en/studies/application/deadline.html</a></td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO231</td>
<td>Das Modul bietet eine kurze Einführung in einige Komponenten und Prozesse des hydrologischen Kreislaufs. Dabei werden einzelne Wasserspeicher (Schnee-, Boden und Grundwasser) und Flüsse zwischen den Speichern (Verdunstung, Niederschlag und Abfluss) betrachtet. Übungen ergänzen die Vorlesung.</td>
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<tr>
<td>651-4088-01L</td>
<td><strong>Physical Geography I (Fundamentals and Spheres)</strong> (University of Zurich)</td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline.html">https://www.uzh.ch/cmsssl/en/studies/application/deadline.html</a></td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: GEO111</td>
<td>Grundlagen zu Wissenschaftskonzepten und globalen Zusammenhängen bezüglich Atmo-, Litho-, Kryo-, Hydro-, Pedo- und Biosphäre.</td>
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<tr>
<td>651-1617-00L</td>
<td><strong>Geophysical Fluid Dynamics and Numerical Modelling</strong> Seminar</td>
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<tr>
<td>651-4931-00L</td>
<td><strong>Seminar I: Heat and Mass Transfers in Magmatology</strong> Does not take place this semester.</td>
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<td>Heat and mass transfers from the mantle to the crust control many aspects of the differentiation of our planet, including (1) primitive melt chemistry, (2) layering of the crust, (3) type of volcanic eruption, (4) formation of mineral deposits. This year, we will focus on processes in crystal mushes (formation, crystallization, remobilization, degassing).</td>
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<td>This class will allow the students to learn about the modern methods and ideas on heat and mass transfers in magmatology through classic and recently published papers. Communication of scientific results to the scientific community and the public is critical. In the class, the students will read and analyse scientific papers and discuss them orally to the class. The students will also create a Wikipedia page and reformulate scientific results for the public.</td>
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<td>The class will focus mostly on 1) reading literature on topics of interests, 2) oral and written presentations of the papers, 3) exercises illustrating the topic, to allow students to work by themselves on some well-defined problems.</td>
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<tr>
<td>651-1091-02L</td>
<td><strong>Geological Colloquium</strong></td>
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<td></td>
<td>Invited speakers from the entire range of Earth Sciences.</td>
<td>Selected themes in sedimentology, tectonics, palæontology, geophysics, mineralogy, paleoclimatic and engineering geology on a regional and global scale.</td>
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<td>According to variable program.</td>
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<td>The presentations are held in German. Membership of the Geological Society in Zurich is not required.</td>
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<tr>
<td>651-3280-00L</td>
<td><strong>Earth Science Excursions</strong></td>
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**Data:** 14.12.2021 12:41  
**Autumn Semester 2021**  
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Only for MSc and doctorate students of D-ERDW. Only for excursions that are not part of the BSc excursion program 2.-6. semester.

With the registration for an excursion or a field course students acknowledge having read and understood the General Terms and Conditions for Field Trips and Excursions [https://www.ETHZ.ch/content/dam/ethz/special-interest/erdw/department/dokumente/studium/exkursionen/AGB-ERDW_Exkursionen_en.pdf]

**Abstract**
Advanced Earth Science Excursions for students with a special interest in Earth Science field studies.

**Objective**
Geological principles and observations in the field

**Prerequisites / notice**
Only for excursions outside of the Bachelor excursions 2.-6. semester program. The program varies from year to year, details published on [https://www.conference.ethz.ch/erdw/](https://www.conference.ethz.ch/erdw/)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2001-00L</td>
<td>Semester Research Project</td>
<td>W</td>
<td>3 credits</td>
<td>Lecturers</td>
</tr>
<tr>
<td>651-4191-00L</td>
<td>Radionuclides as Environmental Tracers</td>
<td>W</td>
<td>3 credits</td>
<td>N. Casacuberta Arola, M. Christl, L. Wacker, C. Welte</td>
</tr>
<tr>
<td>651-4105-00L</td>
<td>Paleomagnetism</td>
<td>W</td>
<td>3 credits</td>
<td>A. Biedermann</td>
</tr>
<tr>
<td>651-4906-00L</td>
<td>Radiocarbon Dating</td>
<td>W</td>
<td>2 credits</td>
<td>C. Welte, L. Wacker</td>
</tr>
</tbody>
</table>

**Abstract**
Small individual research project done by a student and supervised by a Professor/Dozent/Oberassistent of D-ERDW. The content of each project is unique and is defined by the supervisor. The project consists of generating new scientific results and/or data. Short scientific report/paper is written by the student, which serves as a basis for project grading.

**Objective**
- To learn logic, content and methodology of research aimed at producing new scientific results and/or data.
- To familiarize with research procedures in a selected scientific area.
- To obtain experience in writing scientific reports/papers.

**Content**
The content of each project is unique and not related to the BSc or MSc Thesis. This content is defined by the supervisor and discussed with the student, who agrees to the project. The project should mainly consist of research activity aimed at producing new scientific results and/or data and cannot be limited to a literature work. Short scientific report is written by the student at the end of the project, which serves as a basis for the project grading.

**Prerequisites / notice**
Grading criteria for the Semester project is similar to these for an MSc project according to the assessment criteria of the MSc Project Proposal.

The Semester Research Project has a clear-defined scope of work that is not related to the BSc or MSc Thesis.

The binding deadline is set individually by student and supervisor when registering for the project.

**Abstract**
Radionuclides stemming from natural and artificial sources are powerful tools that allow gaining a better understanding of a large range of environmental processes. This course will focus on cosogenic and anthropogenic radionuclides and will provide a general overview about common applications and the use of tracers in the environment, e.g. to understand past climatic changes and ocean currents.

**Objective**
Students learn the basic facts about sources and fate of natural and artificial long-lived radionuclides (e.g. 14C, 26Al, 10Be, 129I, 236U, Pu-isotopes, etc.). They gain insights into the different detection techniques, with special focus on accelerator mass spectrometry (AMS). A selection of the numerous applications of the different radionuclides in oceanic, atmospheric and terrestrial processes will be studied.

**Content**
The course will include lectures, practical exercises and two excursions, namely the opportunity to visit the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the AMS facilities at ETH (Laboratory of Ion Beam Physics).

Lectures will cover:
- an introduction to natural and artificial radionuclides;
- a general overview of radionuclide detection, in particular AMS will be studied including a tour to the Laboratory of Ion Beam Physics;
- applications of long-lived radionuclides in the different environmental compartments (oceans, atmosphere and terrestrial environments):
  - The use of 14C in oceanic, atmospheric and terrestrial studies including a tour to the WSL labs;
  - applications of 10Be in ice cores and marine sediments;
  - applications of nuclear wastes from nuclear accidents (e.g. Fukushima);
  - controlled releases from nuclear reprocessing plants and their role in understanding oceanic processes.

Exercise classes will include an introduction to the Ocean Data View and basic course in applying box models to describe transport and mixing processes. As an evaluation, students will have to hand in a series of exercises related to the different topics of the lecture.

**Prerequisites / notice**
The content of this course is interdisciplinary and it will benefit from students coming from different fields. Two lab tours are organized. This course is also well suited for Ph.D. students. Students will need to bring their own computer that allow installing Ocean Data View.

**Abstract**
This course focuses on the Earth’s magnetic field and the magnetization recorded in rocks as a way to study its past. In addition to mineral magnetism, field and laboratory methods, and data analysis are covered, as well as the wide range of applications of magnetic methods in Earth sciences, e.g. magnetostratigraphy, studies of the early Earth, geodynamics or structural and tectonic studies.

**Objective**
Gain an understanding of how paleomagnetism can be used to study the Earth

**Content**
1. Earth’s magnetic field
2. Mineral magnetism
3. Magnetic remanence
4. Paleomagnetic sampling and tests of stability
5. Data analysis and statistics
6. Paleomagnetic poles and paleogeography
7. Laboratory measurements
8. Topics requested by course participants (anisotropy, magnetostatigraphy, magnetotaxis,...)

**Lecture notes**
Slides will be provided during the lecture

**Literature**
Paleomagnetism: Magnetic Domains to Geologic Terranes by R.F. Butler
[http://www.geo.arizona.edu/Paleomag/](http://www.geo.arizona.edu/Paleomag/)

Essentials of Paleomagnetism by L. Tauxe
[https://earthref.org/MagIC/books/Tauxe/Essentials/](https://earthref.org/MagIC/books/Tauxe/Essentials/)

**Abstract**
Radiocarbon (14C) dating is the most eminent dating tool for carbon containing samples younger than ~50 kyr and a useful tracer of the carbon cycle. Within this lab course, the sample preparation and 14C analysis of wood samples (or upon agreement other samples) will be performed.

**Prerequisites / notice**
Number of participants limited to 6.
Please contact the lecturer for details immediately after subscription.
In this hands-on block course, students will have the opportunity to perform radiocarbon analysis of wood samples. This will include understanding the theoretical background of radiocarbon dating and its importance within Earth Sciences and related fields. Participants will gain know-how on the preparation of wood samples for AMS analysis. They will learn about the importance of suitable reference materials when performing AMS analysis. Data evaluation for C-14 measurements will be performed and discussed.

Content
Sampling of tree ring layers.
Preparation of reference materials and samples for AMS measurement, including chemical pre-treatment and graphitisation.
Assisting the AMS measurement.
Data evaluation and interpretation of results.

Prerequisites / notice
This is a block course for D-ERDW or D-USYS master or PhD students.
Recommended (but not a prerequisite 651-4191-00L Radionuclides as Environmental Tracers (in Autumn Semester) OR 651-4901-00L Quaternary Dating Methods (in Autumn Semester)

651-4145-00L Seminar on Precambrian Geobiology and Biogeochemical Cycles

Abstract
The Precambrian Earth experienced several environmental states—all drastically different from today—that are recorded in sedimentological, fossil, and genetic records. We will review “classic” and more recent scientific literature on the evolution of chemical and biological processes to critically evaluate what we do and don’t know about how our planet’s biogeochemistry has changed through time.

Objective
For decades, researchers have attempted to reconstruct Precambrian environmental states and their relative timing using tracers recorded in the sedimentological, fossil, and genetic records. Here, by reading and discussing “classic” and more recently published scientific papers, students will learn about influential discoveries related to Earth history within the fields of geobiology and geochemistry.

In completing the course, students will specifically learn:
* Why Earth’s surface chemical composition evolved from anoxic to oxic environments
* How life evolved from simple prokaryotic metabolisms to multicellular eukaryotes
* The importance of geological, chemical, and biological feedback mechanisms
* How to discern between biologic innovation and environmental importance
* How to summarize, interpret, and discuss current evidence for what is and isn’t known about Earth’s geochemical and geobiological evolution
* How to assess opposing scientific viewpoints and outstanding questions in the literature

Content
Each lecture period will consist of a presentation and discussion—to be led by 1-2 students (depending on class size)—covering a given paper or set of papers. All students are expected to read the relevant papers before class and come prepared for discussion. Lecture periods will be divided between “review” presentations aimed at introducing the background and fundamentals of each topic and “debate” or “comparison”-style presentations, in which two (sometimes opposing) views of a given topic will be discussed and assessed.

Lecture notes
Where available, presentations and notes will be provided online during the course.

Literature
All required and recommended scientific publications will be provided online during the course.

Choice of courses from the complete offerings in Earth Sciences MSc

GESS Science in Perspective
see Science in Perspective: Language Courses ETH/UZH
see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-ERDW.

Master's Project Proposal

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
651-4060-00L | MSc Project Proposal | O | 10 credits | 21A | Lecturers

The introductory lecture on conduct as a scientist is an integral part of the course.

The MSc Project Proposal is only offered in autumn semester, a registration in spring semester is subject to special approval by the study director.

The main purpose of the Master Project Proposal is to help students organize ideas, material and objectives for their Master Thesis, and to begin development of communication skills.

The main objectives of the Master Project Proposal are to demonstrate the following abilities:
- to formulate a scientific question
- to present scientific approach to solve the problem
- to interpret, discuss and communicate scientific results in written form
- to gain experience in writing a scientific proposal

Master's Thesis

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
651-4062-00L | Master's Thesis | O | 30 credits | 64D | Lecturers

Only students who fulfill the following criteria are allowed to begin with their master thesis:
- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme;
- c. have successfully completed the MSc Project Proposal

The master programme will be completed by a master thesis on a topic selected from the subject range of the chosen major programme. Students are to prove their skills in working autonomously on a scientific project.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.
Complex numbers. C. Liebske

Comprehensive understanding of role and evolution of oceanic and continental lithosphere in global plate tectonics and evolution of earth.

Fundamentals of Geology

Mathematics as a tool to solve engineering problems. Mathematical formulation of technical and scientific problems. V. Picotti, W. Behr

Mathematical tools for the engineer

Fundamentals of Geophysics

Analysis I and II

Physics I

Physics II

Tectonics

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

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

Abstract

Objective

Content

Literature


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

651-3070-AAL  Fundamentals of Geology E- 6 credits 13R  V. Picotti, W. Behr

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

651-3400-AAL  Fundamentals of Geochemistry E- 6 credits 13R  C. Liebske, P. A. Sossi

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

Abstract

Self-study course. This course is only available for those who got it as an additional requirement in their MSc admission.

Objective

The course is intended to let the student learn fundamentals of geochemistry that were found lacking in his/her studies prior to entering the MSc in Earth Sciences at ETH. Contents of the course will be defined based on text books and/or scientific papers.

406-0243-AAL  Analysis I and II E- 14 credits 30R  M. Akveld

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

Abstract

Mathematical tools for the engineer

Objective

Mathematical formulation of technical and scientific problems.

Content

Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.


Literature

Textbooks in English:

Textbooks in German:
- M. Akveld, R. Sperb: Analysis I, vdf
- M. Akveld, R. Sperb: Analysis II, vdf
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

406-0062-AAL  Physics I E- 5 credits 11R  A. Vaterlaus

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

Abstract

Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective

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

The student should acquire an overview over the basic concepts in mechanics.

Content

Book:

Chapters:
1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without: 8-9), 9, 10 (without: 10-10), 11 (without: 11-7), 13 (without: 13-13, 13-14), 14 (without: 14-6), 15 (without: 15-3, 15-5)

Literature

see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik
Wiley-VCH Verlag, 2002, 544 S, ca.: Fr. 68.-

651-3521-AAL  Tectonics E- 3 credits 6R  T. Gerya, W. Behr

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

Abstract

Comprehensive understanding of role and evolution of oceanic and continental lithosphere in global plate tectonics and evolution of earth.

Objective

Understanding principles of theoretical and experimental geothermics and fundamentals of mantle and lithosphere rheologies.

Content

529-2001-AAL  Chemistry I and II  E-  9 credits  19R  J. Cvengros
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

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

Abstract  General Chemistry I and II: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium, kinetics, acids and bases, electrochemistry

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

Content  1. Stoichiometry
2. Atoms and Elements (Quantenmechanical Model of the Atom)
3. Chemical Bonding
4. Thermodynamics
5. Chemical Kinetics
6. Chemical Equilibrium (Acids and Bases, Solubility Equilibria)
7. Electrochemistry

Lecture notes  Nivaldo J. Tro  Chemistry - A molecular Approach (Pearson), Chapter 1-18

406-0603-AAL  Stochastics (Probability and Statistics)  E-  4 credits  9R  M. Kalisch
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

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

Abstract  Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective  The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content  From “Statistics for research” (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation
Introduction to Engineering Geology

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

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

Abstract
This introductory course starts from a description of the behavior and phenomena of soils and rocks under near surface loading conditions and their key geotechnical properties. Lab and field methods for the characterization of soils, rocks and rock masses are introduced. Finally practical aspects of ground engineering, including tunneling and landslide hazards are presented.

Objective
Understanding the basic geotechnical and geomechanical properties and processes of rocks and soils. Understanding the interaction of rock and soil masses with technical systems. Understanding the fundamentals of geological hazards.

Content

Lecture notes
Lecture Material as defined in German PPT Slides of the German Course "651-3525-00L Ingenieurgeologie". Moodle Course Materials available.

Literature
For English speakers study chapters 1-3 of Part I of the book “Geological Engineering” (Gonzalez de Vallejo & Ferrer 2011, CRC Press), without groundwater flow, consolidation time, geophysical methods, details of triaxial tests in soils and rocks, details of clay mineralogy.

Prerequisites / notice
Participate on all exercises of "651-3525-00L Ingenieurgeologie", Tuesday 13-14 pm. Participate in Written Exam together with students of the German Course.

Earth Sciences Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>E-</th>
<th>3 credits</th>
<th>6R</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</tbody>
</table>

Key for Hours

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

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### 851-0240-00L Human Learning (EW1)

- **Abstract:** This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

- **Objective:** Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

- **Content:**
  - Themenatische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen

- **Lecture notes:** Folien werden zur Verfügung gestellt.

- **Literature:**

- **Prerequisites / notice:** This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and adolescence.

#### 851-0238-01L Support and Diagnosis of Knowledge Acquisition Processes (EW3)

- **Abstract:** In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

- **Objective:**
  1. You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
  2. You have a basic understanding about psychological test theory and can appropriately administer tests.
  3. You know various techniques of formative assessment and can apply these to uncover students' misconceptions.

- **Lecture notes:** Folien werden zur Verfügung gestellt.

- **Literature:**

- **Prerequisites / notice:** This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.
## Science Education Master

### Educational Science (for all Directions)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

### Abstract

This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

### Objective

Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

### Content


### Literature


### Prerequisites / notice

This course is only apt for students who intend to enrol in the programs “Lehrdiplom” or “Didaktisches Zertifikat”. It is about learning in childhood and adolescence.

## Biological Direction

### Specialised Courses

### Introductory Courses

### Spec. Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0238-01L</td>
<td>Support and Diagnosis of Knowledge Acquisition Processes (EW3)</td>
<td>W</td>
<td>3</td>
<td>3S</td>
<td>P. Edelsbrunner, J. Maue, C. M. Thurn</td>
</tr>
</tbody>
</table>

### Abstract

In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

### Objective

- The main goals are:
  - You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
  - You have a basic understanding about psychological test theory and can appropriately administer tests.
  - You know various techniques of formative assessment and can apply these to uncover students’ misconceptions.

## Specialised Biology Course with an Educational Focus (6+6 CP)

The Specialised Biology Course with an Educational Focus consists of two modules (6 CP each). In the fall semester, the focus is on evolution. The module of the spring semester deals with biological concepts. Students attending both modules can start with either module.

### Prerequisites

- Successful completion of the Specialised Biology Course with an Educational Focus (6+6 CP) can be acknowledged, in agreement with the advisor of the respective elective major, as one of the two obligatory research projects (each 15 CP). In such a case, additional 3 CP must be obtained in another course.

- In case of overbooking of the course, students enrolled in the Teaching Diploma in Biology will have priority.
Implementation of Subject Didactics I and II with the focus on conducting biological experiments in schools. This includes finding, testing and further developing suitable protocols for different subject areas of school biology. Working out how to didactically embed the experiments in lessons. Students can perform, off the cuff, 12 school experiments (which they have tested themselves), from the different subject areas, and conduct these correctly in technical terms. They can incorporate these experiments in their tuition in a didactically meaningful manner.

Comments:
By contrast to the Subject Specialisation 1 and 2 course units, these are "basic tests" and do not involve the implementation of current research topics. The students' compilations are available in a data archive.

Content
2. Die Studierenden führen alle ausgearbeiteten Experimente selber durch.

Lecture notes
Hand out of course material.

Prerequisites / notice
Der Teil biologische Experimente findet im Rahmen von 7 Halbtagen statt.

---

### Subject Didactics Biology I

**Number**: 551-0971-00L

**Title**: Subject Didactics Biology I

*Simultaneous enrolment in Introductory Internship Biology*

**Abstract**
- Basic conditions for tuition (MAR - recognition of Matura certificates - curricula, standards), selection of topics and reduction of the complexity of topics.
- Application of teaching methods and techniques from educational science in biology classes.
- Planning and preparation of lessons.

**Objective**
- Students can discuss and put into practice in their teaching work the conditions and objectives set out in the regulations governing the school-leaving examination (Matura), the framework curriculum and the conditions and objectives specified by their school.
- They are in a position to select learning objectives and formulate these on the basis of the target level model. They can plan and prepare lessons and can also develop appropriate learning assignments.
- Students can reconstruct specialist contents in didactic terms and develop teaching modules suitable for the different levels from these on the basis of the subject structure and learner requirements.
- They can reduce the complexity of subject-based specialist contents and present them in such a way that they are comprehensible and meaningful for learners.
- They can select appropriate media for their work (e.g. school books) and use these. They can employ appropriate experiments.
- The students can use different forms of examination for monitoring performance.
- Students are in a position to implement and discuss the concepts of biology teaching and learning on the basis of specific topics covered in school biology.

**Content**

**Lecture notes**
Wird laufend in der Vorlesung abgegeben.

**Prerequisites / notice**
Studierende müssen LE zusammen mit dem Einführungspraktikum - LE 551-0968-00L - belegen.

---

### Teaching Science in Higher Education

**Number**: 402-0091-00L

**Title**: Teaching Science in Higher Education

This course imparts fundamental didactic concepts that are relevant to teaching science in a Higher Education context.

**Abstract**
Students are able to transfer the basic concepts of this model (ILO, TLA, assessment, constructive alignment) to science education.

**Objective**
- Planning and preparation of lessons.
- Application of teaching methods and techniques from educational science in biology classes.

**Lecture notes**
keines

**Literature**

(If the book was available in the fall of 2011, you should have purchased it for the first meeting.)
### Introductory Courses

Selection of courses will be agreed with the course coordinator.

### Spec. Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0962-00L</td>
<td><strong>Fundamental Aspects of Chemistry with an Educational Focus B</strong></td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>A. Togni, R. Alberto</td>
</tr>
</tbody>
</table>

**Information for UZH students:**
Enrolment to this course unit only possible at ETH. No enrolment to module CHE406 at UZH.

**Examination Registration only at ETH.**

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/university-of-zurich.html

**Abstract**
Selected topics in general chemistry:
1. The language of chemistry
2. Chirality and stereochemistry
3. Oxidation of water
4. Chemistry of the atmosphere

**Objective**
In this course, participants acquire extended and more in-depth knowledge of selected chemistry topics. The selection is based on a large extent on the partial aspects of chemistry that are typically taught at high school. By gaining a broader understanding, teachers are put in a position where they can comprehend the topics that are to be taught in a wider and, to some extent, unconventional context and critically process these in respect of their teachability and learnability. At the same time, interrelationships between the classical sub-disciplines of chemistry are highlighted, along with the unique features of chemistry as one of the central natural sciences.

**Content**
Content of the four modules:
1. The language of chemistry: Concepts, formulas, aesthetics, and philosophical aspects
2. Chirality and stereochemistry: Selected aspects, origin of biomolecular chirality, inorganic chemistry
3. Cosmochemistry
4. Chemistry of the atmosphere

**Lecture notes**
Folien und ausgewählte Literatur werden zur Verfügung gestellt.

**Literature**
Ausgewählte Artikel aus der Primärliteratur werden vorgestellt, kommentiert und zur Lektüre empfohlen.

**Prerequisites / notice**
FV A (gelesen im Frühjahrsemester) und FV B (gelesen im Herbstsemester) bauen nicht aufeinander. Die Reihenfolge der Belegung ist somit indifferent

### Subject Didactics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0950-00L</td>
<td><strong>Subject Didactics Chemistry I</strong></td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>A. Baertsch</td>
</tr>
</tbody>
</table>

**Abstract**
Simultaneous enrolment in Introductory Internship Chemistry - course 529-0962-00L - is compulsory.

**Objective**
The students have basic subject didactic knowledge for teaching chemistry at a secondary school. They are able to design lessons that are effective for learning, actively involve students in lessons, explain challenging concepts simply, use experiments for theory and reflect on teaching.

**Content**
Schwerpunkte im ersten Studiensemester bilden die folgenden Themen:
- Auswahl gymnasiumsrelevanter Lerninhalte
- Didaktische Vereinfachung
- Modelle und chemischen Formeln zur Beschreibung von Aufbau und Umwandlung der Substanzen
- Wechselwirkungen zwischen Beobachtung in der realen Welt und Deutung auf Modell-Ebene
- Skizzen entwerfen und zur Erklärung von Reaktionen nutzen
- Chemie im 8. Schuljahr: Das Teilchenmodell erklärt viele Phänomene im Anfangsunterricht
- Atommmodelle und chemische Bindung
- Radioaktivität und Kernspaltung
- Struktur und Eigenschaft
- Auswahl, Konzeption, Vorbereitung, Durchführung, Einbettung und Auswertung von Demonstrations-Experimenten

**Lecture notes**
Die Unterlagen sind auf der Plattform http://ftochemie.pbworks.com zugänglich

**Literature**
- E. Rossa: Chemie-Didaktik, Cornelsen Verlag, 2015
- H.-J. Bader et al: Konkrete Fachdidaktik Chemie, Oldenbourg Verlag, 2002

**Prerequisites / notice**
Der Chemieunterricht am Gymnasium soll einerseits grundlegende chemische Kenntnisse für den Alltag vermitteln und andererseits auf ein naturwissenschaftlich orientiertes Hochschulstudium vorbereiten. Diese beiden Ziele sind im Unterricht gleichermaßen zu berücksichtigen.

Da viele Lerninhalte sequentiell und einander benützend strukturiert sind, ist dem logischen Aufbau des Unterrichts besonderes Augenmerk zu schenken. Dies bedingt eine feine Abstimmung von fachlichen Inhalten und didaktischen Methoden auf die kognitive Leistungsfähigkeit der Lernenden.

Anhand der Diskussion bewährter Beispiele und dem Entwurf eigener Unterrichtsbausteine soll die zukünftige Lehrperson befähigt werden, einen den spezifischen Rahmenbedingungen angepassten Unterricht zu entwickeln, der diesem hohen Qualitätsanspruch genügt.

### 402-0091-00L

**Teaching Science in Higher Education**

**Abstract**
This course imparts fundamental didactic concepts that are relevant to teaching science in a Higher Education context.

**Objective**
Students are able to characterize and to discuss the model of outcomes based education.

**Lecture notes**
keines
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories (assessed)
- Techniques and Technologies (assessed)

Domain B - Method-specific Competencies
- Analytical Competencies (assessed)
- Decision-making (assessed)
- Problem-solving (assessed)
- Project Management (assessed)

Domain C - Social Competencies
- Communication (assessed)
- Cooperation and Teamwork (assessed)
- Customer Orientation (assessed)
- Leadership and Responsibility (assessed)
- Self-presentation and Social Influence (assessed)
- Sensitivity to Diversity (assessed)
- Negotiation (assessed)

Domain D - Personal Competencies
- Adaptability and Flexibility (assessed)
- Creative Thinking (assessed)
- Critical Thinking (assessed)
- Integrity and Work Ethics (assessed)
- Self-awareness and Self-reflection (assessed)
- Self-direction and Self-management (assessed)

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Specialised Courses

Introductory Courses

Selection of courses will be agreed with the course coordinator.

Spec. Courses in Respective Subject with Educational Focus

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

Objective

Why is energy important for life and our society? How did energy use change over time? Which effects did these changes have on the environment? What are the physical basics of energy technologies? When, why and how did technology and science of energy come together? What are the limits and benefits of all the various energy technologies? How can different energy technologies be compared? Can we understand the changes in the current energy systems? How will the energy systems of the future look like? How fast can we and should we alter the current energy transition? Which could be the overall guide lines for a working energy system of the future?

Content


Lecture notes

Web page:
http://ihp-ix2.ethz.ch/energy21/index.html

Literature

The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Smil, 2018
Renewable Energy – Without the Hot Air, D.J.C. Mackay 2009

Prerequisites / notice

Basics of Physics applied to Energy and Energy Technology. Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions. Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

Subject Didactics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0910-00L</td>
<td>Physics Didactics I: Special Didactics of Physics Teaching</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>

Limited number of participants. Further information is available from the lecturer via email: mamohr@ethz.ch

Simultaneous enrolment in Introductory Internship Physics - course 402-0920-00L - is compulsory for Teaching Diploma Physic

Information for UZH students:
### Natural Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-3001-00L</td>
<td>Dynamic Earth I</td>
<td>W</td>
<td>6</td>
<td>4+2U</td>
<td>O. Bachmann, A. Galli, A. Fichtner, M. Schönbrücher, S. Willert</td>
</tr>
</tbody>
</table>

Abstract: Provides a basic introduction into Earth Sciences, emphasizing different rock-types and the geological rock-cycle, as well as introduction into geophysics and plate tectonic theory.

Objective: Understanding basic geological and geophysical processes

Content: Overview of the Earth as a system, with emphasis on plate tectonic theory and the geological rock-cycle. Provides a basic introduction to crystals and minerals and different rock-types. Lectures include processes in the Earth’s interior, physics of the earth, planetology, introduction to magmatic, metamorphic and sedimentary rocks. Exercises are conducted in small groups to provide more in depth understanding of concepts and content of the lectures.

Lecture notes: werden abgegeben.


Prerequisites / notice: Exercises and short excursions in small groups (10-15 students) will be lead by student assistants. Specific topics in earth sciences will be discussed using examples and case studies. Hand samples of the major rock types will be described and interpreted. Short excursions in the region of Zurich will permit direct experience with earth science processes (e.g. earth surface processes) and recognition of earth science problems and solutions relevant for modern society (e.g. building materials, water resources). Working in small groups will allow for discussion and examination of actual earth science themes.
### Science Education Master - Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
</tbody>
</table>

| O  | Compulsory                           |
| Z  | Courses outside the curriculum       |
| Dr | Suitable for doctorate               |

### Key for Hours

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

**ECTS**

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETHZ Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<td></td>
<td>- Get information about recent literature on learning and instruction</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td></td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
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<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>Number of participants limited to 30.</td>
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<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- Understanding of research methods used in the empirical human sciences</td>
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<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1 credit</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>Number of participants limited to 30.</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- Understand research methods used in the empirical educational sciences</td>
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<td></td>
<td>- Understand and critically examine information from scientific journals and media</td>
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<tr>
<td></td>
<td>- Understand pedagogically relevant findings from the empirical educational sciences</td>
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<tr>
<td>851-0242-11L</td>
<td>Gender Issues In Education and STEM</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
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<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues</td>
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<td></td>
<td>- To develop a critical view on existing research and perspectives.</td>
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<td></td>
<td>- To integrate this knowledge with teacher’s work.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them. The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td></td>
<td>Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).</td>
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<tr>
<td>851-0229-00L</td>
<td>Using Outdoor Education</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>R. Schumacher, P. Faller</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma Biology and Geography.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>In this seminar, future teachers will be trained to prepare and conduct excursions to out-of-school learning venues. For this purpose, excursions are offered at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf.</td>
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</tbody>
</table>
Objective

Future teachers will learn to prepare and conduct excursions to out-of-school learning venues.

Content

Excursions at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Birmensdorf:
- Dendrochronology: What annual rings tell
- Photosynthesis/Climate change: The tracks in the forest
- Forest Soil: The soil in the focus of the climate

Subject Didactics in Geography

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4239-00L</td>
<td>Didactics Geography I (University of Zurich)</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>University lecturers</td>
</tr>
<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.</td>
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<tr>
<td></td>
<td>UZH Module Code: 090GG1</td>
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<tr>
<td></td>
<td>Limited number of participants.</td>
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<tr>
<td></td>
<td>In addition to the course enrollment a registration by email is required to Dr. Stefan Hesske (E-Mail: <a href="mailto:stefan.hesske@ife.uzh.ch">stefan.hesske@ife.uzh.ch</a>).</td>
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<tr>
<td></td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Fundamentals (theory and practice) of specialist subject teaching for high-school geography lessons.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>A maximum of 12KP additional requirements in Geography may be open before registering for the didactics Geography.</td>
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<tr>
<td></td>
<td>Please provide the form <a href="https://ethz.ch/content/dam/ethz/main/education/didaktische-ausbildung/Files/Diverses/Form_Auflagen_bis%2012%20KP_291015.pdf">https://ethz.ch/content/dam/ethz/main/education/didaktische-ausbildung/Files/Diverses/Form_Auflagen_bis%2012%20KP_291015.pdf</a> as a confirmation.</td>
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<tr>
<td>651-4124-00L</td>
<td>Examination Didactics</td>
<td>O</td>
<td>1</td>
<td>2G</td>
<td>S. Hesske, J. Rafflenbeul</td>
</tr>
<tr>
<td>Abstract</td>
<td>Die Prüfung Fachdidaktik bildet den Abschluss der didaktischen Ausbildung und wird nach erfolgreichem Abschluss aller Ausbildungsbereiche der didaktischen Ausbildung abgelegt.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Geprüft werden: Fähigkeit, Geografie-Unterricht mit Bezug zur eigenen Praxis kritisch und unter verschiedenen Blickwinkeln (inhaltlich, methodisch-didaktisch) zu betrachten, Lernarrangements mit Bezug zum heutigen Bildungs- und Schulfachverständnis zu gestalten und kritisch zu hinterfragen sowie deren möglichen/erzielten Wirkungen zu diskutieren und zu begründen; Unterrichtssituationen zu reflektieren und zu evaluieren.</td>
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<tr>
<td>Lecture notes</td>
<td>Unterlagen aus der fachdidaktischen Ausbildung</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Takes place at the end of the studies, prerequisites: successful completion of the program.</td>
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<tr>
<td>Taught competencies</td>
<td>The examination didactics is an 15-minutes oral exam that takes place at the same day together with the examination lessons I and II.</td>
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</tbody>
</table>

Taught competencies

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

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

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

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

<table>
<thead>
<tr>
<th>651-4120-00L</th>
<th>Geography Didactics IV: Mentored Project</th>
<th>O</th>
<th>2</th>
<th>4A</th>
<th>S. Hesske, J. Rafflenbeul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerequisites: successful participation in Geography Didactics of Geography Teaching I, II, III</td>
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<tr>
<td>Abstract</td>
<td>Mentorierte Arbeit mit Bezug zur fachdidaktischen Ausbildung.</td>
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</tr>
<tr>
<td>Objective</td>
<td>selbständige, theoriegestützte Auseinandersetzung mit konkreter, praxisbezogener Fragestellung zum Geographieunterricht.</td>
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</tr>
<tr>
<td>Content</td>
<td>selbständige, mentorierte Arbeit zu einem Thema aus der Fachdidaktik mit direktem Bezug zur Lehrpraxis im Fach Geografie (z.B. zu eigenen Übungslektionen und Praktikum oder zur Unterrichtsforschung).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>May be completed together with didactics III at the earliest.</td>
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</tbody>
</table>
### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Media and Digital Technologies | assessed |
| Problem-solving | not assessed |
| Project Management | not assessed |
| Domain C - Social Competencies | Communication | assessed |
| Cooperation and Teamwork | assessed |
| Customer Orientation | not assessed |
| Leadership and Responsibility | not assessed |
| Self-presentation and Social Influence | not assessed |
| Sensitivity to Diversity | not assessed |
| Negotiation | not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Integrity and Work Ethics | not assessed |
| Self-awareness and Self-reflection | assessed |
| Self-direction and Self-management | assessed |

#### 651-4118-00L Geography Didactics of Geography Teaching III (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: 090GG3

Limited number of participants. In addition to the course enrollment a registration by email is required no later than September 1 for autumn semester, February 1 for spring semester. Further details see UZH module.

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

**Abstract**

Working with medias in Geography teaching:


**Prerequisites / notice**

Geography Didactics III may be completed in parallel with Geography Didactics II, but only after successful completion of Geography Didactics I.

### Professional Training in Geography

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>651-2519-01L</td>
<td>Introductory Internship (University of Zürich)</td>
<td>O</td>
<td>1 credit</td>
<td>2P</td>
<td>University lecturers</td>
</tr>
<tr>
<td>651-2519-02L</td>
<td>Practice Lessons for Didactics (University of Zurich)</td>
<td>O</td>
<td>2 credits</td>
<td>4P</td>
<td>University lecturers</td>
</tr>
<tr>
<td>651-2517-00L</td>
<td>Teaching Internship I Geography (University of Zürich)</td>
<td>O</td>
<td>8 credits</td>
<td>17P</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

The Introductory Internship belongs to the practical expertise education of the teacher training for Upper Secondary Schools and must be completed at the beginning of studies.

The Introductory Internship must be completed together with the practice lessons for didactics.

The Practice Lessons can only be completed together with an accredited internship teacher of ETH Zurich (separate list).
In the context of their first teaching practice, students compile a portfolio in which they analyse and document selected aspects of their teaching experience. On the basis of a specified topic, the candidate shows that they are in a position to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

The Introduced Internship can only be completed together with an accredited internship teacher of ETH Zurich (separate list).

### 651-2520-01L  
**Examination Lesson I Geography**  
To be completed together with Examination Lesson II 651-2520-02.  

**Abstract**  
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**  
On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**  

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

**Prerequisites / notice**  
Takes place at the end of the studies, prerequisites: successful completion of the program.

The examination lessons I and II must be enrolled and completed together with the examination didactics.

### 651-2520-02L  
**Examination Lesson II Geography**  
To be completed together with Examination Lesson I 651-2520-01.  

**Abstract**  
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

**Objective**  
On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

**Content**  

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

**Prerequisites / notice**  
Takes place at the end of the studies, prerequisites: successful completion of the program.

The examination lessons I and II must be enrolled and completed together with the examination didactics.

### 651-4137-00L  
**Semester Paper Within the 1st Teaching Internship Geography (University of Zurich)**  
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

**UZH Module Code:** 090BPP1

Mind the enrolment deadlines at UZH:  
[https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html](https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html)

**Abstract**  
In the context of their first teaching practice, students compile a portfolio in which they analyse and document selected aspects of their teaching experience.

**Prerequisites / notice**  
Only for students of the Geography Teaching Diploma.

The semester paper must be completed together with the first teaching internship, the registration is therefore in the same semester.


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2517-02L</td>
<td><strong>Teaching Internship II-E Geography (University of Zurich)</strong></td>
<td>O</td>
<td>6</td>
<td>13P</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

**UZH Module Code:** 090BPP2

An additional registration at LLBM is needed for further details refer to the module of UZH.

Mind the enrolment deadlines at UZH:  
[https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html](https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html)
The course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

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

This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

This course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Lecture notes
Assigned reading materials and slides will be available via Moodle.

Literature
Assigned reading materials and slides will be available via Moodle.
This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

### Additional Requirements (ETH-Masterstudents in ERDW and AC)

#### Part 1

#### Compulsory Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2601-00L</td>
<td>Human Geography I: One Earth - Many Worlds (University of Zurich)</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

**Abstract**

Imparting of research questions and basic principles in Human Geography

**Objective**

- To get an overview about basic research questions and principles of Human Geography
- (1) Society and space (2) Society and development (structure and dynamic of population, urbanisation, disparities (3) Society and natural environment (natural resources; food security, sustainability)

**Literature**


**Number**

651-2613-00L | Human Geography III (Geographies of Difference) (Universität Zürich) | O | 5 credits | 1G+2S | University lecturers |

**Abstract**

This re-search-oriented course enables students to think through and about difference in a geographically (multi-scalar, critical, space-bound) manner, by elaborating on multiple concepts from postcolonial, intersectional and other disciplinary debates, and by applying these to specific topical domains.

**Objective**

- Knowledge
  - Understand basic concepts and empirical manifestations of difference in human geography
  - Deepen knowledge on how difference works in one specific topic of human geography
- Skills
  - Learn to independently digest, assess, and present basic academic texts
  - Conduct discussions in English or German (online and offline) - Be able to write a short research paper about a human geography topic

#### Modules of Choice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2603-00L</td>
<td>Geography. Matters. (University of Zurich)</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

**Abstract**

The course demonstrates geography’s interdisciplinary approach to contribute solving urgent challenges ahead of society. Students are encouraged to reflect on the value of interdisciplinary research at discipline level and on their individual interdisciplinary curricula. The course creates awareness of ways that concepts structure our thinking, and how they figure in research and practice.

#### Part 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4088-03L</td>
<td>Physical Geography III (Geomorphology and Glaciology) (University of Zurich)</td>
<td>W</td>
<td>5 credits</td>
<td>1V+1U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>
Mind the enrolment deadlines at UZH:

Abstract
Das Modul bietet eine kurze Einführung in einige Komponenten und Prozesse des hydrologischen Kreislaufes. Dabei werden einzelne Wasserspeicher (Schnee-, Boden und Grundwasser) und Flüsse zwischen den Speichern (Verdunstung, Niederschlag und Abfluss) betrachtet. Übungen ergänzen die Vorlesung.

Part 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-2338-00L</td>
<td>Remote Sensing and Geographic Information Science III (University of Zürich)</td>
<td>W</td>
<td>5 credits</td>
<td>2V+3U</td>
<td>University lecturers</td>
</tr>
<tr>
<td>103-0214-00L</td>
<td>Cartography Fundamentals</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>L. Hurni</td>
</tr>
</tbody>
</table>

Abstract
Exercises to the course Introduction Remote Sensing.

Objective
Acquire basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics. Ability to assess existing products with respect to their content-related and design quality. Ability to design proper plans and well designed legends for basic maps.

Content
Definitions "map" and "cartography", map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analog and digital map production technology, prepress technology, printing technology, topographic maps, map critics.

Lecture notes
Will be distributed module by module.

Literature

Prerequisites / notice
Further information at http://www.karto.ethz.ch/studium/lehrangebot.html

Geography Teaching Diploma - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
# Bachelor’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0006-00L</td>
<td>Bachelor’s Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

**Abstract**

The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work.

**Objective**

Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Content**

The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

---

**Key for Hours**

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

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Geomatics Master

#### Major Courses

##### Major in Engineering Geodesy and Photogrammetry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0287-00L</td>
<td>Image Interpretation</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>K. Schindler</td>
</tr>
<tr>
<td>103-0137-00L</td>
<td>Engineering Geodesy</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>A. Wieser, J. Qiao</td>
</tr>
<tr>
<td>103-0267-01L</td>
<td>Photogrammetry and 3D Vision Lab</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>C. Albl</td>
</tr>
<tr>
<td>103-0787-00L</td>
<td>Project Parameter Estimation</td>
<td>W</td>
<td>3</td>
<td>3P</td>
<td>J. A. Butt, T. Medic</td>
</tr>
<tr>
<td>102-0617-00L</td>
<td>Basics and Principles of Radar Remote Sensing for Environmental Applications</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>I. Hajnsek</td>
</tr>
</tbody>
</table>

#### Prerequisites / notice

- fundamental knowledge of machine learning; basic knowledge of image processing
- basic knowledge of machine learning; basic knowledge of image processing
- 3 credits
- 3 credits
- 3 credits
- 3 credits
- 3 credits
- 3 credits
- 4 credits

#### Content

- Preprocessing of satellite images, atmospheric correction; extraction of features (radiometric indices, texture descriptors, etc.) from raw image intensities; semantic image segmentation (e.g., cloud masking); physical parameter estimation (e.g., vegetation height); practical deployment of classical machine learning algorithms as well as deep neural networks for remote sensing data analysis; assessment of prediction results
- Introduction: Definition, methods, and tasks
- Planning and realizing geodetic networks
- High precision distance, angle and height measurements
- Sensors and multi-sensor-systems
- Calibration and testing
- Engineering Geodesy in construction above and below ground
- Tunnel surveying
- Building Information Modeling (BIM)
- Deformation monitoring: Models, methods, and applications
- Deformation monitoring: Models, methods, and applications
- Deformation monitoring: Models, methods, and applications
- Deformation monitoring: Models, methods, and applications
- The students will be introduced to the methods, instruments and applications in Engineering Geodesy with a focus on end-to-end quality assessment, sensor and multi-sensor-systems, setting out, and monitoring of engineering objects. They will be able to acquire enhanced knowledge and fundamental competences in high-precision angle, distance and height measurements. They will be introduced to aspects of interdisciplinary work in particular related to construction processes and civil engineering.
- The aim of the course is to provide a hands-on experience with close-range photogrammetry. The students will go through all aspects of 3D reconstruction starting with the image acquisition, camera calibration, automatic sparse geometry reconstruction, and eventually produce a final textured 3D model.
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- The aim of the course is to familiarize the students with both the practical aspects of close-range photogrammetric reconstruction and the theoretical foundations behind them. After passing the course, the students should be able to plan the image acquisition, perform the camera calibration, build a structure-from-motion pipeline using modern open-source libraries, produce a 3D model, and improve its quality.
- The aim of the course is to familiarize the students with both the practical aspects of close-range photogrammetric reconstruction and the theoretical foundations behind them. After passing the course, the students should be able to plan the image acquisition, perform the camera calibration, build a structure-from-motion pipeline using modern open-source libraries, produce a 3D model, and improve its quality.
- The course should provide an understanding of SAR techniques and the use of the imaging tools for bio/geophysical parameter estimation. At the end of the course the student has the understanding of SAR basics and principles, SAR polarimetry, SAR interferometry, and environmental parameter estimation from multi-parametric SAR data.
The course is giving an introduction into SAR techniques, the interpretation of SAR imaging responses and the use of SAR for different environmental applications. The outline of the course is the following:

1. Introduction into SAR basics and principles
2. Introduction into electromagnetic wave theory
3. Introduction into scattering theory and decomposition techniques
4. Introduction into SAR interferometry
5. Introduction into polarimetric SAR interferometry
6. Introduction into bio/geophysical parameter estimation (classification/segmentation, soil moisture estimation, earth quake and volcano monitoring, forest height inversion, wood biomass estimation etc.)

**Objective**

The students will get an understanding of the nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs). The Swiss cadastral system as well as a range of international approaches both in developed and developing countries will be reviewed.

**Content**

Origins and purposes of cadastral systems
Importance of documentation
Basic concepts of cadastral systems (real estate, legal basis, conceptual principles, property-ownership, property types)
Swiss cadastral system:
- legal basis
- organization
- technical elements
- methods of data acquisition and maintenance
- profession
- quality assurance
Digital revolution, access to data
Benchmarking and evaluation of cadastral systems
International trends, developments and initiatives

**Lecture notes**

Handouts for each topic will be provided

**Literature**

Complete literature listing will be provided during the course.

**Course Code**

103-0687-00L

**Course Title**

Cadastral Systems

**Credit Points**

W 2 credits 2G D. M. Steudler

**Abstract**

Nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs).

**Lecture notes**

see: http://www.geo21.ch/ethz/

**Literature**


**Prerequisites / notice**

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

**Course Code**

263-5902-00L

**Course Title**

Computer Vision

**Credit Points**

W 8 credits 3V+1U+3A M. Pollefeys, S. Tang, F. Yu

**Abstract**

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

**Objective**

The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

**Content**

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

**Prerequisites / notice**

Basic probability theory and statistics, linear algebra, basic programming skills

**Course Code**

103-0820-00L

**Course Title**

Introduction to Scientific Computation

**Credit Points**

W 3 credits 2G M. Usvyatsov

**Abstract**

Introduction to tools, techniques, and methods for data processing and analysis.

**Objective**

Get ready to work with data of different origin. Learn Python and tools to the level which allows attacking data related problems. Basic introduction to numerical algorithms for efficient problem solving

**Content**

Python for scientific programming, fast numerical computations and data visualisation.
Libraries for data processing.

**Prerequisites / notice**

Basic probability theory and statistics, linear algebra, basic programming skills

**Course Code**

851-0724-01L

**Course Title**

Real Estate Property Law

**Credit Points**

W 3 credits 3V M. Huser, R. Müller-Wyss, S. Stucki

**Abstract**

Particularly suitable for students of D-ARCH, D-BAUG, D-USYS

Fundamental concepts of Land Register Law and Land Surveying Law (substantive and procedural rules of Land Register Law, the parts and the relevance of the Land Register, process of registration with the Land Register, legal problems of land surveying, reform of the official land surveying).

**Objective**

Overview of the legal norms of land registry and surveying law.

**Content**

Basic principles of material and formal land registry law, components of the land register, consequences of the land register, the registration process, legal problems of surveying, the reform of official surveying, liability of the geom-eter.

**Lecture notes**

Abgegebene Unterlagen: Skript in digitaler Form

Pflichtlektüre: Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Beiträge aus dem Institut für schweizerisches und internationales Baurecht der Universität Freiburg/Schweiz, Zürich 2014
Topics covered in this lecture include: time series analysis, Fourier transformation, stochastic processes, ARMA, analytical and numerical

Space Geodesy Lab allows you to deepen your knowledge about space-geodetic techniques, in particular of GNSS, VLBI, satellite altimetry and gravity missions for monitoring the environment and changes within the Earth system.

Students enrolled in this course will be given the possibility to learn about space-geodetic methods to solve a specific research problem. As a result, you will become familiar with the entire processing chain from gathering of raw measurements to geodetic products like reference frames, station motions, Earth orientation parameters, atmospheric and climate variables, or the Earth gravity field and its variations.

For a small project based on space geodetic measurements and methods (or a related project of your choice), you or a group of 2-3 students will be provided with the necessary equipment, access to data and analysis tools for solving a research question. Therefore, we expect autonomous development, planning, data analysis and interpretation of the results. At the end of the semester you will be asked to present your findings and to submit a report summarizing your semester activities. As needed, further background will be given during the semester.

Lecture notes
Script M. Rothacher – Space Geodesy lecture notes
Additional literature will be distributed during lectures

Prerequisites / notice
Basic knowledge about satellite geodetic, reference frames and the Earth gravity field. Programming skills in Matlab, Python or similar.

103-0627-00L

Space Geodesy Lab

W

5 credits

3P

G. Möller, R. Hohensinn, M. Rothacher, B. Soja

Abstract
Space Geodesy Lab allows you to deepen your knowledge about space-geodetic techniques, in particular of GNSS, VLBI, SLR, satellite altimetry and gravity missions for monitoring the environment and changes within the Earth system.

Objective
Students enrolled in this course will be given the possibility to learn about space-geodetic methods to solve a specific research problem. As a result, you will become familiar with the entire processing chain from gathering of raw measurements to geodetic products like reference frames, station motions, Earth orientation parameters, atmospheric and climate variables, or the Earth gravity field and its variations.

Content
For a small project based on space geodetic measurements and methods (or a related project of your choice), you or a group of 2-3 students will be provided with the necessary equipment, access to data and analysis tools for solving a research question. Therefore, we expect autonomous development, planning, data analysis and interpretation of the results. At the end of the semester you will be asked to present your findings and to submit a report summarizing your semester activities. As needed, further background will be given during the semester.

Lecture notes
div. sources

Literature
M. Rothacher – Space Geodesy lecture notes
Additional literature will be distributed during lectures

Prerequisites / notice
Basic knowledge about satellite geodetic, reference frames and the Earth gravity field. Programming skills in Matlab, Python or similar.

103-0087-01L

Signal Processing, Modeling, Inversion

O

3 credits

2G

B. Soja

Abstract
Topics related to time series analysis, modeling, parameter estimation, prediction, and interpretation. Theoretical concepts will be applied to geodetic problems.

Objective
Students have various methods at hand to mathematically formulate specific scientific problems. They are able to analyse observational data, estimate numerical and analytical models, and predict parameters into the future. The students can evaluate and interpret measurements and models derived from them. They know the necessary terminology in order to study expert literature.

Content
Topics covered in this lecture include: time series analysis, Fourier transformation, stochastic processes, ARMA, analytical and numerical modeling, model selection, linear and non-linear parameter estimation, sequential parameter estimation and filtering, machine learning for time series analysis and prediction, interpretation of measurements and derived results. The theoretical concepts will be illustrated by concrete examples commonly found in geodetic applications.

Lecture notes
Lecture slides and notes

Literature
Script Alain Geiger: Geoprocessing
Additional literature will be referred to in class

Prerequisites / notice
Courses corresponding to: Analysis I+II, Linear Algebra I, Parameter Estimation

103-0187-01L

Space Geodesy

O

4 credits

3G

M. Rothacher

Abstract

Objective
Understanding the major observation techniques in space geodesy as modern methods applied in Earth system monitoring (geometry, rotation and gravity field of the Earth and the atmosphere), in national surveying and navigation.

Content
Overview of GNSS, Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Satellite Radar Altimetry with the basic principles, the instruments and observation equations. Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters.

Equation of motion of the unperturbed and perturbed satellite orbit. Osculating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

Lecture notes
Script M. Rothacher “Space Geodesy”
Taught
competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed
Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management assessed
Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity not assessed
Negotiation not assessed
Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-presentation and Self-reflection not assessed
Self-direction and Self-management not assessed

103-0787-00L Project Parameter Estimation W 3 credits 3P J. A. Butt, T. Medic
Abstract Solving engineering problems with modern methods of parameter estimation for network adjustment in a real-world scenario; choosing adequate mathematical models, implementation and assessment of the solutions.
Objective Learn to solve engineering problems with modern methods of parameter estimation in a real-world scenario.
Content Analysis of given problems, selection of appropriate mathematical models, implementation and testing using Matlab: Kriging; system calibration of a terrestrial laser scanner.
Lecture notes The task assignments and selected documentation will be provided as PDF.
Prerequisites / notice Prerequisite: Statistics and Probability Theory, Geoprocessing and Parameterestimation, Geodetic Reference Systems and Networks

102-0617-00L Basics and Principles of Radar Remote Sensing for Environmental Applications W 3 credits 2G I. Hajnsek
Abstract The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.
Objective The course should provide an understanding of SAR techniques and the use of the imaging tools for bio/geophysical parameter estimation. At the end of the course the student has the understanding of
1. SAR basics and principles,
2. SAR polarimetry,
3. SAR interferometry and
4. environmental parameter estimation from multi-parametric SAR data
Content The course is giving an introduction into SAR techniques, the interpretation of SAR imaging responses and the use of SAR for different environmental applications. The outline of the course is the following:
1. Introduction into SAR basics and principles
2. Introduction into electromagnetic wave theory
3. Introduction into scattering theory and decomposition techniques
4. Introduction into SAR interferometry
5. Introduction into polarimetric SAR interferometry
6. Introduction into bio/geophysical parameter estimation (classification/segmentation, soil moisture estimation, earth quake and volcano monitoring, forest height inversion, wood biomass estimation etc.)
Lecture notes Handouts for each topic will be provided
Literature First readings for the course:
Complete literature listing will be provided during the course.

103-0687-00L Cadastral Systems W 2 credits 2G D. M. Steudler
Abstract Nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs).
Objective The students will get an understanding of the nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs). The Swiss cadastral system as well as a range of international approaches both in developed and developing countries will be reviewed.
Content Origins and purposes of cadastral systems
Importance of documentation
Basic concepts of cadastral systems (real estate, legal basis, conceptual principles, property-ownership, property types)
Swiss cadastral system:
- legal basis
- organization
- technical elements
- methods of data acquisition and maintenance
- profession
- quality assurance
Digital revolution, access to data
Benchmarking and evaluation of cadastral systems
International trends, developments and initiatives
Lecture notes see: http://www.geo21.ch/ethz/
see also: http://www.geo21.ch/ethz/
Real Estate Property Law

Abstract
Fundamental concepts of Land Register Law and Land Surveying Law (substantive and procedural rules of Land Register Law, the parts and the relevance of the Land Register, process of registration with the Land Register, legal problems of land surveying, reform of the official land surveying).

Objective
Overview of the legal norms of land registry and surveying law.

Content
Basic principles of material and formal land registry law, components of the land register, consequences of the land register, the registration process, legal problems of surveying, the reform of official surveying, liability of the geom-eter.

Lecture notes
Abgegebene Unterlagen: Skript in digitaler Form

Literature
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Beiträge aus dem Institut für schweizerisches und internationales Baurecht der Universität Freiburg/Schweiz, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.

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

Major in GIS and Cartography

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0227-00L</td>
<td>Cartography III</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>L. Hurni</td>
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<tr>
<td>Abstract</td>
<td>This follow-up course proceeds to a complete Web map project and introduces in 3D and animated cartography.</td>
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<tr>
<td>Objective</td>
<td>This course enables students to plan, design and realize interactive Web map projects. The introduction to 3D and animated cartography also provides a general knowledge about animated 3D graphics.</td>
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<tr>
<td>Content</td>
<td>- Web mapping.</td>
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<td></td>
<td>- Data processing.</td>
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<td></td>
<td>- Interaction design.</td>
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<td></td>
<td>- Graphical user interface.</td>
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<td></td>
<td>- 3D cartography.</td>
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<td>- Animated cartography.</td>
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<td></td>
<td>- Video production.</td>
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<tr>
<td>Lecture notes</td>
<td>Handouts of the lectures and exercise documents are available on Moodle.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Further information at <a href="http://www.karto.ethz.ch/studium/lehrangebot.html">http://www.karto.ethz.ch/studium/lehrangebot.html</a></td>
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<tr>
<td>103-0237-00L</td>
<td>GIS III</td>
<td>O</td>
<td>5 credits</td>
<td>3G</td>
<td>W. Kuhn</td>
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<tr>
<td>Abstract</td>
<td>The course deals with advanced topics in GIS, such as Business aspects and Legal issues; Geostatistics; Human-Computer Interaction; Cognitive Issues in GIS; Geosensors; Spatial Data Mining and Machine Learning for GIS.</td>
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<td>Objective</td>
<td>Students will get a detailed overview of advanced GIS topics. They will work on a small project with geosensors in the lab and perform practical tasks relating to Geostatistics and Machine Learning.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture slides will be made available in digital form.</td>
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<tr>
<td>103-0747-00L</td>
<td>Cartography Lab</td>
<td>W</td>
<td>6 credits</td>
<td>13A</td>
<td>L. Hurni</td>
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<tr>
<td>Abstract</td>
<td>Independent practical work in cartography</td>
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<tr>
<td>Objective</td>
<td>Independent practical work in cartography</td>
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<tr>
<td>Content</td>
<td>Choice of theme upon individual agreement</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Cartography III</td>
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<td>Multimedia Cartography</td>
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<td>Further information at <a href="http://www.karto.ethz.ch/studium/lehrangebot.html">http://www.karto.ethz.ch/studium/lehrangebot.html</a></td>
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<tr>
<td>103-0687-00L</td>
<td>Cadastral Systems</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>D. M. Steudler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs).</td>
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</tbody>
</table>
The students will get an understanding of the nature, role and importance of cadastral systems and related concepts such as land administration, land registration and spatial data infrastructures (SDIs). The Swiss cadastral system as well as a range of international approaches both in developed and developing countries will be reviewed.

**Topics**
- System-neutral and model-driven approach with reality selection, conceptual modeling, flexible standard formats, one-to-one processors, semantic transformation.
- Conceptual schema languages (UML and INTERLIS), data formats (ITF, XML), tools (ILI-Checker, Python, UMLT, FME, ModelBaker).

**Topics**
- Explain and apply the model-driven approach based on standards
- Describe and use interoperability types
- Describe transfer formats and reformat them by one-to-one processors
- Explain object-oriented modelling (based on graphical and textual representation)
- Describe and use communication technologies and OGC Web services
- UML, EBNF, INTERLIS, ITF, XML, Python, FME, ModelBaker (QGIS), and PostgreSQL
- Apply appropriate software tools

**Prerequisites / notice**
Condition for participation: Successful bachelor course GIS II (old) or Geoinformationstechnologien und –analysen, GTA (new)

**851-0724-01L**

**Objective**
Particularly suitable for students of D-ARCH, D-BAUG, D-USYS

**Abstract**
Fundamental concepts of Land Register Law and Land Surveying Law (substantive and procedural rules of Land Register Law, the parts and the relevance of the Land Register, process of registration with the Land Register, legal problems of land surveying, reform of the official land surveying).

**Content**
Overview of the legal norms of land registry and surveying law.

**Lecture notes**
Abgegebene Unterlagen: Skript in digitaler Form

**Literature**
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Beiträge aus dem Institut für schweizerisches und internationales Baurecht der Universität Freiburg/Schweiz, Zürich 2014
- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Zürich 2014
- Meinrad Huser, Geo-Informationssrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.
Major in Planning

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0347-00L</td>
<td>Landscape Planning and Environmental Systems</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>A. Grêt-Regamey</td>
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<tr>
<td>Abstract</td>
<td>In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.</td>
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<tr>
<td>Objective</td>
<td>The aims of this course are:</td>
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<td></td>
<td>1) To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna);</td>
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<td>2) To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.</td>
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<td>3) To show the importance of ecosystem services.</td>
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<td>4) To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).</td>
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<td>5) To identify and measure the characteristics of landscape.</td>
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<td>6) Learn how to use spatial data in landscape planning.</td>
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<td>Content</td>
<td>In this course, the following topics are discussed:</td>
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<td>- Definition of the concept of landscape</td>
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<td>- Relevance of landscape planning</td>
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<td>- Landscape metrics</td>
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<td>- Landscape change</td>
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<td></td>
<td>- Methods, instruments and aims of landscape planning (policy)</td>
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<td></td>
<td>- Socio-political questions of the future</td>
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<td>- Environmental systems, ecological connectivity</td>
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<td></td>
<td>- Ecosystem services</td>
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<td></td>
<td>- Urban landscape services</td>
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<td></td>
<td>- Practice of landscape planning</td>
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<td></td>
<td>- Use of GIS in landscape planning</td>
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<tr>
<td>Lecture notes</td>
<td>No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.</td>
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</table>

The focus of the lecture Site & Project Development is on larger contiguous areas or sites and their urban, open space and infrastructural development. In this course, students work on a semester exercise in which they "develop" a specific large-scale project from practice and evaluate it economically, strategically and in terms of feasibility.

Students in this course will pursue the following learning objectives:

- Investigate and understand a given concrete project area and identify, evaluate and articulate the current problems and relevant issues within this area.
- Consolidate their knowledge in the essential topics of site & project development and apply this in a well-founded, argued and creative manner to address the task at hand.
- Organize and structure themselves while acquiring responsibilities in their interdisciplinary project teams. The teams consist of three to five fellow students that must develop innovative, viable and resilient concepts for a real project development in a given area. Their considerations should be presented in written form (project report) and in linguistic-visual form (final presentation). At the end of the course, the students critically reflect on their experiences with the group work process together with the course instructors.
- Acquire methodological knowledge in location & market analysis, 3D visualization of a project as well as in the financial assessment of a large-scale real estate project and use this knowledge to justify their considerations and evaluate their proposal.

The lecture is divided into several thematic sections analogous to the essential topics of Site & Project Development. The students are accompanied both in the semester exercise and in the individual lectures by a large number of external guest speakers from the praxis-field, which means that the lecture will not only thematically examine the relevant areas of Site & Project Development, but also will offer the students exclusive, practice-oriented insights. The relevant methodological knowledge for the semester exercise is imparted and, due to the proximity to practice, the students gain exclusive insights into possible professional fields of activity. In this lecture, students apply their already acquired and newly learned skills, especially in interdisciplinary teams, and work on an exciting, motivating and relevant question from the practice.

Major topics covered in the lecture include:
- Urban planning
- Location and market analysis
- Real estate development, financing and valuation
- Project development and decision-making from the perspective of investors
- Open space design and landscape architecture
- Sustainable building and sustainability certification
- Mobility, parking issues, travel models
- Cooperative planning and participation processes, mediation
- Gendered planning in project development
- Inner development & urban quality

Parallel to the lecture series, students work in interdisciplinary teams on a real-life task. In the course of the semester exercise, the lecture material is deepened and what has been learned is applied. The students visit the project area at the beginning of the semester as part of an excursion. Specific large-scale projects such as the Gaswerkareal Bern, the Sihl-Manegg Areal Zurich (Greenocity) or the Areal Alter Platusmarkt (Nidfeld) Lucerne will be dealt with. For the possible development of the given site, visions are developed by the students on the basis of a comprehensive location and market analysis and a utilization concept is developed. In the process, the students are accompanied by experts and regularly discuss their ideas and proposed solutions with their supervisors.

Lecture notes

- Handouts of the lectures
- Extracts from relevant scientific articles and theory literature
- Exercise material

Download: https://irl.ethz.ch/de/education/vorlesungen/msc/project_development.html

References in the lecture notes

None

Prerequisites / notice

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

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

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

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

103-0317-00L Introduction to Spatial Development and Transformation

Only for master students, otherwise a special permission by the lecturer is required.

Abstract

The course deals with important theoretical, material and methodical foundations for action and decision-making of spatial relevance. This course discusses central tasks and possible solutions for current and future challenges of spatial development in Switzerland and Europe.
Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

The lecture introduces necessary basic knowledge and is based on the following main topics:
- Inward development and challenges of spatial transformation
- Planning approaches and The (political) steering of spatial development
- Interplay of formal and informal processes and processes across different scales of spatial development
- Methods of action-oriented planning in situations of insecurity
- Integrated space and infrastructure development
- Different types of participation in spatial development

By taking up the lecture, the students are able to recognize cross-scale, complex tasks of spatial development and transformation and to use their theoretical, methodical and professional knowledge to clarify them.

Further information and the documents for the lecture can be found on the homepage of IRL/STL.
The course is based on the following questions:

How do we deal with complex issues in planning?
- Forms of knowledge, half-knowledge and not knowing
- Occurrence and explanation patterns for irrational behaviour
- Spatial research and planning practice
- Planning maxims
- Mapping complex topics in research questions

How do we generate knowledge about complex issues?
- Methods for scientific data generation
- Applied handling of quantities and probabilities
- Estimating despite uncertainties
- Opportunities of digitisation in planning (Participation, BigData)

How do we react to complex questions in planning?
- Methods of scientific data analysis
- Making decisions despite incomplete information
- Dealing with robustness and fragility

More specifically, the lectures focus on the following topics (NB: Some content units will be presented in English, they are marked with *asterisk below):
- (Half-) knowledge/behaviour/irrationalities
- Initial situation: Solving complex problems
- Behavioural patterns, occurrence and explanation patterns for irrational behaviour
- Methods for solving complex tasks in planning practice
- Spatial research and planning practice - connections, differences, overlaps
- Challenges in the solution of complex tasks: System delimitation, interdisciplinarity, retrospective vs. prospective approach (descriptive vs. action-oriented, *reflected scenario building*)
- Planning maxims
- *Methodology in spatial research
- *Research design
- *Research ethics
- Decisions based on incomplete information
- Dealing with complex systems/roughness
- *Role of science in planning - the perspective of both research and practice

Learning materials: available online (Moodle) before corresponding lecture.


This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system.
Objective

Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view.

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
general introduction of transport, modes, technologies, system design and line planning for different situations,
timetabling and tactical planning, and related mathematical approaches
operations, and quantitative support to operational problems,
evaluation of public transport systems.

Content

Basics for line transport systems and networks
Passenger/Supply requirements for line operations
Objectives of system and network planning, from different perspectives and users, design dilemmas
Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport
Planning process, from demand evaluation to line planning to timetables to operations
Matching demand and modes
Line planning techniques
Timetabling principles
Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes

Lecture slides are provided.

Literature

Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)

Taught competencies

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

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

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

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

101-0417-00L Transport Planning Methods W 6 credits 4G K. W. Axhausen

Abstract

The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

### Lecture notes
Moodle platform (enrollment needed)

### Literature


### Landscape Planning and Environmental Systems (GIS W)
#### 103-0347-01L

**Abstract**
The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

**Objective**
- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Developing landscape planning measures for practical case studies

**Content**
- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

**Lecture notes**
A script and presentation slides for each exercise will be provided on Moodle.

**Literature**
Will be named in the lecture.

**Prerequisites / notice**
Basic GIS skills are strongly recommended.

### European Aspects of Spatial Development
#### 103-0569-00L

**Abstract**
Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

**Objective**
Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making
- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the relevance of planning culture and planning system; planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

Obligatory literature:

Recommended literature:
- Governance models:

- Planning models:

- EU as a political context:

Territorial cooperation in Europe:

Planning families and cultures:


Planning systems in Europe:

Prerequisites / notice

Only for master students, otherwise a special permission by the lecturer is required.

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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

Electives

The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

Recommended Electives of Master Degree Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-1065-00L</td>
<td>Design Thinking: Human-Centred Solutions to Real World Challenges</td>
<td>W</td>
<td>5 credits</td>
<td>5G</td>
<td>S. Brusoni</td>
</tr>
</tbody>
</table>

Does not take place this semester.
Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Content
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Prerequisites / notice
Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session. Please note also that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

101-0193-00L
Systemic Design Labs: RE:GENERATE Alpine-Urban

- W 4 credits
- 2S
- T. Luthe

Systemic Design (SD) optimizes an entire system as a whole, rather than its parts in isolation. SD is iterative, recursive and circular, requires creative, curious, informed and critical systems thinking and doing, yielding radical resource efficiency. It systems mapping, design thinking, footprint assessment, network analysis, test planning, prototyping, fabrication, social experiments.

The teaching purpose of Systemic Design Labs (SDL) is to better tackle the complexity of today’s sustainability challenges. Often, in current education we learn to disassemble design challenges into their bits and parts for individual optimization. While being useful for developing topical expertise, this reductionism to parts with less emphasis on their interaction does not match with the growing complexity of today's challenges. In contrast, systemic design approaches a task from a holistic perspective, zooming out of a system to reveal its structure and connections between its parts – to zoom in on the hub of influence that matters most. The objectives of the course are to introduce students to Systemic Design to theory, methodology and practice. This includes whole systems thinking, circularity, cross-scale design, Gigamapping, and many more. The course stimulates overall reflective eco-social thinking in design, planning and engineering disciplines.

Design Challenge: How to re-design alpine-urban circularity? How to revive mountain livelihoods, focusing on local identity, resilient landscapes and a regenerative economy? What's a regenerative relation between the alpine and the urban? Covid has accelerated and intensified a traditionally challenging relation of the alpine (mountain livelihoods) and the urban. Both depend on each other, but there are as well many unsustainable elements in this relation, especially for the alpine.

The specific design challenge is to identify and layout a holistic, partly quantified and visualized systems strategy for building a resilient community economy in relation to the actual Covid driven pressure factors in the relation of the alpine with the urban. We build upon former ETH SDL students who developed a systems maps for the community of Ostana, Italy, that embraces local identity, revitalizes cultural and landscape biodiversity, and creates alpine-urban circularity.

This course will extend this systems map to more clearly understand the urban component, the source market, and design in new opportunities of urban-alpine regeneration, for circularity, for new ways of tourism, of mobility, in a creative economy.

Recap of former SDL courses:
In Ostana, a clear connection is between the local identity (culture, traditions, visions) which is formed by Occitan culture (food, music, dance, language), traditional stone building architecture which is under pressure to carefully evolve with new needs for carbon-neutral and net-positive buildings, and the Monte Viso landscape. How does a re-growing economy that should be regenerative and circular by design, correlate with innovation in architecture, with population growth and associated challenges in mobility, waste systems and supplies, with net-positive buildings, and the Monte Viso landscape. How does a re-growing economy that should be regenerative and circular by design, correlate with innovation in architecture, with population growth and associated challenges in mobility, waste systems and supplies, with net-positive buildings, and the Monte Viso landscape.

Deliverables & output: This SDL course RE:GENERATE builds upon related work from former courses hosted and lead by the MonViso Institute (i.e. on social innovation, mobility, architecture and local identity, tourism, circular economy, land use change) to develop and design foundations for an extension of the existing, visualized and partly quantified systems map, that will support ongoing and future innovation processes in this community. The focus now is on the urban integration into new, regenerative business models of the alpine, and in regenerative relation between both as a model for the future. This course will thus develop an extended graphical systems map from the alpine to the urban, backed up by a technical report, and connected with the existing systems maps of Ostana and the surrounding valley.

Lecture notes
see learning materials and https://systemicdesignlabs.ethz.ch/.

Literature
Depending on the Covid situation, some part of the course will be virtual via Zoom, using a Miro design board. If possible, we will do a field trip. Some travel costs may apply. Students need to be motivated to design in teams on the preparation of the deliverables, a systemic strategy map and a written report.

Prerequisites / notice

Depending on the Covid situation, some part of the course will be virtual via Zoom, using a Miro design board. If possible, we will do a field trip. Some travel costs may apply. Students need to be motivated to design in teams on the preparation of the deliverables, a systemic strategy map and a written report.

Taught competencies

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

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

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

Domain D - Personal Competencies
- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Problem-solving assessed
- Project Management assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

Course Catalogue of ETH Zurich

Seminar Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>103-0817-00L</td>
<td>Geomatics Seminar</td>
<td>O</td>
<td>4 credits</td>
<td>2S</td>
<td>K. Schindler, K. W. Axhausen, A. Grêt-Regamey, L. Hurni, W. Kuhn, M. Rothacher, A. Wieser</td>
</tr>
</tbody>
</table>

Interdisciplinary Project Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>103-0298-02L</td>
<td>Interdisciplinary Project</td>
<td>O</td>
<td>12 credits</td>
<td>24A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

GESS Science in Perspective

- see GESS Science in Perspective: Language Courses
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for
### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0009-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>24 credits</td>
<td>51D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students' ability to work independently and to produce scientifically structured work.

**Objective**
To work independently and to produce a scientifically structured work.

**Content**
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

### Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0132-AAL</td>
<td>Geodetic Metrology Fundamentals</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>A. Wieser</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the most important sensors, operation and calculation methods of Geodetic Metrology

**Objective**
Getting to know the most important sensors, operation and calculation methods of Geodetic Metrology

**Content**
Overview on the different domains of geodetic metrology
- Geodetic instruments and sensors
- Determination of 3D-coordinates with GNSS, total station and levelling
- Calculation methods of geodetic metrology
- Survey and staking-out methods

**Lecture notes**
Slides and additional material used in the associated regular course Geodätische Messtechnik GZ (in German) are provided in electronic form.

**Literature**

**Prerequisites / notice**
The field course is part of this lecture. Practical exercises complete the subjects taught during the semester.

If evidence of equivalent practical experience in surveying cannot be provided by the student, participation in the field course during the respective next available period (i.e. 1 week in the beginning of the summer holidays) is required.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0414-AAL</td>
<td>Transport Planning (Transportation I)</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>K. W. Axhausen</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture course discusses the basic concepts, approaches and methods of transport planning in both their theoretical and practical contexts.

**Objective**
The course introduces the basic theories and methods of transport planning.

**Content**
Basic theoretical links between transport, space and economic development; basic terminology; measurement and observation of travel behaviour; methods of the four stage approach; cost-benefit analysis.

**Literature**

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0153-AAL</td>
<td>Cartography II</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>L. Hurni</td>
</tr>
</tbody>
</table>

**Abstract**
Theory and mathematical basics of the cartographic visualisation of attributed geo-objects for static and interactive maps (with exercises).

**Objective**
The course offers first computer graphics and mathematical basics and concepts of cartography. The accompanying exercises introduce further cartographic and GIS software, programming libraries for cartographic visualisation purposes. It is shown how web browsers, text editors and scripting languages can be used to develop efficient tools for cartographic data processing, design, and visualisation.

**Content**
- Cartographic workflow, data types, data capturing, data sources and legal aspects.
- Introduction to QGIS, ArcGIS and OCAD for cartographic applications.
- Data types: Analytical and visualisation processes in cartography.
- Colour management and pre-press processes.
- Web maps using HTML, CSS, JavaScript, SVG and Canvas 2D.
- Interaction with diagrams and maps.
- Libraries and APIs for cartographic applications.

**Prerequisites / notice**
Cartography Fundamentals or similar introduction courses in Cartography.

<table>
<thead>
<tr>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0214-AAL</td>
<td>Cartography Fundamentals</td>
<td>E-</td>
<td>5 credits</td>
<td>11R</td>
<td>L. Hurni</td>
</tr>
</tbody>
</table>

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

Abstract
Basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics.

Objective
Acquire basic knowhow about communication with spatial information by using plans and maps, about the most important design rules and production methods for map graphics. Ability to assess existing products with respect to their content-related and design quality. Ability to design proper plans and well designed legends for basic maps.

Content
Definitions “map” and “cartography”, map types, current tasks and situation of cartography, map history, spatial reference systems, map projections, map conception and workflow planning, map design, analogue and digital map production technology, prepress technology, printing technology, topographic maps, map critics.

Lecture notes
Will be distributed module by module.

Literature
- E. Brockmann


discipline: 3D Imaging, deGruyter, 2020

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

Abstract
This course provides basic knowledge on parameter estimation and data processing. The necessary mathematical and statistical methods are developed and are applied to actual examples in geomatics.

Objective
The students are capable of analysing measurements with with appropriate methods. They can optimally extract model parameters from real measurements and are able to analyse and to retrieve additional information from time series. They understand the underlying algorithms of different geodetic analysis tools and processing methods.

103-0254-AAL Photogrammetry E- 6 credits 13R K. Schindler

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

Abstract
The class conveys the basics of photogrammetry. Its aim is to equip students with an understanding of the principles, methods and applications of image-based 3D measurement.

Objective
The aim is an understanding of the principles, methods and possible applications of photogrammetry. The course also forms the basis for more in-depth studies and self-reliant photogrammetric project work in further photogrammetry-related courses.

Content
The basics of photogrammetry, its products and applications: the principle of image-based triangulation; digital aerial cameras and related sensors; projective geometry; mathematical modeling, calibration and orientation of cameras; photogrammetric reconstruction of points and lines, and stereoscopy; orthophoto generation; digital photogrammetric workstations; recording geometry and flight planning

Literature
- Luhmann, Robson, Kyle, Boehm: Close-Range Photogrammetry and 3D Imaging, deGruyter, 2020

Prerequisites / notice
Requirements: basic knowledge of physics, linear algebra and analytical geometry, calculus, least-squares adjustment and statistics

103-0274-AAL Image Processing E- 3 credits 6R J. D. Wegner

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

Abstract
Introduction to basic concepts and methods of digital image processing.

Objective
Understanding core methods and algorithms in image processing and computer vision and the underlying signal processing foundations. Applying image processing algorithms to relevant problems in photogrammetry and remote sensing.

Content
- Properties of digital images
- Sampling, quantisation and signal processing
- Colour spaces and transformations
- Geometric image transformations
- Image morphology
- Discrete convolution
- Image filtering
- Texture descriptors
- 2D Fourier transform and the Fourier domain
- Pattern recognition: corner and edge extraction
- Image segmentation

Literature
- Jähne, 2012: Digitale Bildverarbeitung und Bildgewinnung, Springer

We suggest the following textbooks for further reading:
Rafael C. Gonzalez, Richard E. Woods
Digital Image Processing
ISBN: 013168728X
Rafael C. Gonzalez, Steven L. Eddins, Richard E. Woods:
Digital Image Processing Using MATLAB
Prentice Hall, 2003
ISBN: 0130085197

103-0313-AAL Spatial Planning and Landscape Development E- 5 credits 11R S.-E. Rabe

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

Abstract
Understanding core methods and algorithms in image processing and computer vision and the underlying signal processing foundations. Applying image processing algorithms to relevant problems in photogrammetry and remote sensing.

Content
- Properties of digital images
- Sampling, quantisation and signal processing
- Colour spaces and transformations
- Geometric image transformations
- Image morphology
- Discrete convolution
- Image filtering
- Texture descriptors
- 2D Fourier transform and the Fourier domain
- Pattern recognition: corner and edge extraction
- Image segmentation

Literature
- Jähne, 2012: Digitale Bildverarbeitung und Bildgewinnung, Springer

We suggest the following textbooks for further reading:
Rafael C. Gonzalez, Richard E. Woods
Digital Image Processing
ISBN: 013168728X
Rafael C. Gonzalez, Steven L. Eddins, Richard E. Woods:
Digital Image Processing Using MATLAB
Prentice Hall, 2003
ISBN: 0130085197
This course unit as an additional admission requirement.

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

Abstract
The lecture introduces into the main-features of spatial planning. Attended will be the subjects of planning as a national responsibility, instruments of spatial planning, techniques for problem solving in spatial planning and the Swiss concept for regional planning.

Objective
- To get to know the interaction between the community and our living space and their resulting conflicts.
- Link theory and practice in spatial planning.
- To get to know instruments and facilities to process problems in spatial planning.

Content
The self-study course compromises the following readings:
- Chapters of: Lynch, Kevin: «The Image of the City».
- Alexander, Christopher et al.: «A Pattern Language».
- Mikoleit, Anne and Pürckhauer, Moritz: «Urban Code».
- «SIDAIA - Spatial and Infrastructure Development: An Integrated Approach».

Lecture notes
The graded semester performance comprises a condensed paper to be written by the student reflecting both the literature read as well as exemplarily applying the knowledge gained from the literature by independently exploring the two city quarters.

Literature
cf. content

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

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

Abstract
Introduction to programming in Java. Procedural foundations of programming and outlook to object oriented programming. Variables, types, assignments, control structures (branch, loop), data structures, algorithms, line graphics, graphical user interface. Writing small programs. Working with a professional programming environment (Eclipse).

Objective
The students will be able to write simple programs and to modify existing programs.

Content
This course offers an introduction to variables, control structures (branch, loop), algorithms and data structures, as well as an outlook to modularisation and object oriented techniques. In the exercises students train programming skills (in the programming language JAVA). Students can solve the exercises on their own laptop or in the computer labs at ETH. The software used in this course runs on MS Windows, MacOS X and Linux.

Prerequisites / notice
Prerequisites:
- 252-0845-00 Computer Science I (D-BAUG)

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

Abstract
Introduction to Linear Algebra and Numerical Analysis for Engineers. This reading course is based on chapters from the book "Introduction to Linear Algebra" by Gilbert Strang (SIAM 2009), and "A first Course in Numerical Methods" by U. Ascher and C. Greif (SIAM, 2011).

Objective
To acquire basic knowledge of Linear Algebra and some aspects of related numerical metjhods and the ability to apply basic algorithms to simple problems.

Content
1 Introduction, calculations using MATLAB
2 Linear systems I
3 Linear systems II
4 Scalar- & vektorproduct
5 Basics of matrix algebra
6 Linear maps
7 Orthogonal maps
8 Trace & determinant
9 General vectorspaces
10 Metric & scalarproducts
11 Basis, basistransform & similar matrices
12 Eigenvalues & eigenvectors
13 Spectral theorem & diagonalisation
14 Repetition

Literature

Prerequisites / notice
Knowledge of elementary calculus
Abstract Mathematical tools of an engineer

Objective Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineers.


Literature Textbooks in English:
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus
- M. Akveld, R. Sperb, Analysis II, vdf
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>406-0243-AAL</td>
<td>Analysis I and II</td>
<td>14</td>
<td>30R</td>
<td>M. Akveld</td>
</tr>
<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>4</td>
<td>9R</td>
<td>M. Kalisch</td>
</tr>
<tr>
<td>103-0357-AAL</td>
<td>Environmental Planning</td>
<td>3</td>
<td>6R</td>
<td>S.-E. Rabe</td>
</tr>
</tbody>
</table>

Abstract Mathematical tools for the engineer

Objective Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers.

Content Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.

Literature Textbooks in English:
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus

Textbooks in German:
- M. Akveld, R. Sperb: Analysis I, vdf
- M. Akveld, R. Sperb: Analysis II, vdf
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

Abstract Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature - "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267395; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435
From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

Abstract The lecture covers tools, methods and procedures of Landscape and Environmental Planning developed. By means of field trips their implementation will be illustrated.
Objective
Knowledge of the various instruments and possibilities for the practical implementation of environmental planning.
Knowledge of the complex interactions of the instruments.

Content
Topics of the Lectures
- forest planning
- inventories
- intervention and compensation
- ecological network
- agricultural policy
- landscape development concepts (LEK)
- parks
- swiss landscape concept
- riverine zone
- natural hazards

Note: there are several non-obligatory field trips as part of the lecture. It is recommended to participate at these to boost the in-depth understanding of the different topics.

Lecture notes
- lecture notes concerning the instruments
- handouts
- copies of selected literature

Download: http://www.plus.ethz.ch/de/studium/vorlesungen/bsc/environmental_planning.html

406-0062-AAL  Physics I
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

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

The student should acquire an overview over the basic concepts in mechanics.

Content
Book:

Chapters:
1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5)

Literature
see "Content"

406-0063-AAL  Physics II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

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

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

Content
Book:

Chapters:

Literature
see "Content"

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 1: Mechanik und Thermodynamik
Wiley-VCH Verlag, 2002, 544 S, ca.: Fr. 68.-

252-0856-AAL  Computer Science
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract

Objective
Primäres Lernziel der Vorlesung ist die Befähigung zum Programmieren mit C++. Studenten beherrschen nach erfolgreichem Abschluss der Vorlesung die Mechanismen zum Erstellen eines Programms, sie kennen die fundamentalen Kontrollstrukturen, Datenstrukturen und verstehen, wie man ein algorithmisches Problem in ein Programm abbildet. Sie haben eine Vorstellung davon, was "hinter den Kulissen" passiert, wenn ein Programm übersetzt und ausgeführt wird.

Sekundäre Lernziele der Vorlesung sind das Computer-basierte, algorithmische Denken, Verständnis der Möglichkeiten und der Grenzen der Programmierung und die Vermittlung der Denkart eines Computerwissenschaftlers.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
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<tr>
<td>103-2233-AAL</td>
<td>GIS Basics</td>
<td>6</td>
<td>E</td>
<td>W. Kuhn</td>
</tr>
<tr>
<td>103-0187-AAL</td>
<td>Satellite Geodesy</td>
<td>4</td>
<td>E</td>
<td>M. Rothacher</td>
</tr>
<tr>
<td>103-1115-AAL</td>
<td>Geodetic Metrology and Laserscanning</td>
<td>6</td>
<td>E</td>
<td>A. Wieser</td>
</tr>
<tr>
<td>103-1184-AAL</td>
<td>Physical and Kinematic Geodesy</td>
<td>6</td>
<td>E</td>
<td>M. Rothacher</td>
</tr>
<tr>
<td>103-0717-AAL</td>
<td>Geoinformation Technologies and Analysis</td>
<td>6</td>
<td>E</td>
<td>W. Kuhn</td>
</tr>
</tbody>
</table>

**Objective**

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

**Abstract**

- Fundamentals in geoinformation technologies: database principles, including modeling of spatial information, geometric and semantic models, topology and metrics; practical training with GIS software.

**Objective**

- The students acquire enhanced knowledge regarding the operating mode, the application and the limitations of modern geodetic standard instruments. They will be able to properly select, test and apply these instruments for geodetic tasks with higher accuracy requirements.

**Content**

- The geomatics workflow
- Satellite Radar Altimetry with the basic principles, the instruments and observation equations. Modelling of the station motions and the estimation of station coordinates. Basics of wave propagation in the atmosphere. Signal propagation in the ionosphere and troposphere for the different observation techniques and the determination of atmospheric parameters. Equation of motion of the unperturbed and perturbed satellite orbit. Osculating and mean orbital elements. General and special perturbation theory and the determination of satellite orbits.

**Literature**


**Content**

- Physical and Kinematic Geodesy: Basics of Shape of the Earth: Geoid determination and deflection of the vertical. Introduction into the most important topics: Satellite Geodesy and Navigation; Physical Geodesy and gravity field of the Earth; Astronomical Geodesy and Positioning; Mathematical Geodesy and basics of Geodynamics. Reference systems and applications in National and Global Geomatics.

**Objective**

- The students will be introduced to specific geodetic tasks related to construction and civil engineering.

**Literature**

### 103-0184-AAL Higher Geodesy

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

**Abstract** Advanced geoinformation technologies and analyses methods: Mobile GIS; Web-GIS & Geo-Web-Services; Spatial Big Data; Temporal aspects in GIS; Analysis of movement data; User interfaces

**Objective** Knowing advanced topics of geoinformation technologies (Mobile GIS and Web-GIS) and spatio-temporal analysis methods for the realization, application and operation of Web-GIS in engineering projects.

**Prerequisites / notice** Introductory GIS course

#### Literature

### 103-0126-AAL Geodetic Reference Systems

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

**Abstract** Modern methods of Higher Geodesy: Basics of Shape of the Earth; Geoid determination and deflection of the vertical. Introduction into the most important topics: Satellite Geodesy and Navigation; Physical Geodesy and gravity field of the Earth; Astronomical Geodesy and Positioning; Mathematical Geodesy and basics of Geodynamics. Reference systems and applications in National and Global Geomatics.

**Objective** Overview over the entire spectrum of Higher Geodesy

**Prerequisites / notice** Introductory GIS course

### 103-0255-AAL Geodata Analysis

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

**Abstract** The course deals with advanced methods in spatial data analysis.

**Objective**
- Understanding the theoretical principles in spatial data analysis.
- Understanding and using methods for spatial data analysis.
- Detecting common sources of errors in spatial data analysis.
- Advanced practical knowledge in using appropriate GIS-tools.

**Content** The course deals with advanced methods in spatial data analysis in theory as well as in practical exercises.


### 103-0234-AAL GIS II

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

**Abstract** Advanced course in geoinformation technologies: conceptual and logical modelling of networks, 3D- and 4D-data and spatial processes in GIS; raster data structures and operations; mobile GIS; Internet and GIS; interoperability and data transfer; legal and technical foundations of spatial data infrastructures (SDI)

**Objective** Students will be able to carry out the following phases of a GIS project: data modelling, mobile data acquisition and analysis, Web publication of data and integration of interoperable geospatial web services into a Spatial Data Infrastructure (SDI).


### 406-0353-AAL Analysis III

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

**Abstract** Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

**Objective** Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.
Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling; Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling; Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform

Prerequisites / notice
Up-to-date information about this course can be found at:
http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet

102-0675-AAL Earth Observation
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

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

Abstract
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.

103-0849-AAL Multivariate Statistics and Machine Learning
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to statistical modelling and machine learning.

Objective
The goal is to familiarise students with the principles and tools of machine learning, and to enable them to apply them for practical data analysis.

Content
multivariate probability distributions; comparison of distributions; regression; classification; model selection and cross-validation; clustering and density estimation; mixture models; neural networks

Literature
- Hastie, Tibshirani, Friedman: The Elements of Statistical Learning, Springer 2009
- Duda, Hart, Stork: Pattern Classification, Wiley 2012

Geomatics Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>E-</th>
<th>Z</th>
<th>Dr</th>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<td>D</td>
<td>Suitable for doctorate</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
History and Philosophy of Knowledge Master

► Basic Courses

►► Lectures and Exercises

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>862-0050-00L</td>
<td>Theorie and Methodology MAGPW</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>F. Forster, L. Schurrer</td>
</tr>
</tbody>
</table>

Abstract
Introduction to methods, theories and work techniques of the disciplines represented in the study programme.

Objective
The interdisciplinary seminar is aimed exclusively at students of the master's program "History and Philosophy of Knowledge". It is designed to give students an insight into the subjects represented in the degree program and their specific requirements, procedures, questions and work techniques.

Prerequisites / notice
Dates: Thursday, 10-12

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0101-88L</td>
<td>National Socialist Persecution, International Politics on Refugees and Science 1933-1945</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Hagner</td>
</tr>
</tbody>
</table>

Abstract
The course discusses the development of National Socialist persecution policy, the reactions of democratic states to the persecution of the Jews and the role of science in the Nazi regime.

Objective
The students are able to distinguish the phases of persecution and know various models to explain how the Holocaust came about. They can situate Swiss refugee policy in an international context. In their engagement with science under National Socialism, they develop an awareness of the socio-political responsibility of science.

Content
The "Nazis" and the "Holocaust" are omnipresent in politics and entertainment industry - often combined with a lack of historical knowledge. The fact that "the Germans," whose achievements in art and science made them one of the world's leading nations, murdered millions of people on an industrial scale, caused widespread horror. This is based on the assumption that education and culture stand in contrast to the "barbarism" of the "Nazis". Therefore, the course pays special attention to the role of science and the academically educated people.

Prerequisites / notice
The course combines lecture and tutorial. Active participation in class through short presentations and working papers is required. This requires 1-2 hours of preparation time per week in addition to class attendance.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>851-0157-00L</td>
<td>Mind and Brain</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Hagner</td>
</tr>
</tbody>
</table>

Abstract
In the last 2500 years, the mind-brain relationship has been articulated in various ways. In these lectures, I will explore the scientific and philosophical aspects of this relationship in the context of relevant cultural, historical and technological processes, with a focus on the modern neurosciences, but I will also discuss works of art and literature.

Objective
By the end of this lecture, students should be familiar with essential positions in the scientific and philosophical treatment of questions relating the mind to the brain. It should also become clear that some of the most relevant problems in current neurosciences have a long history.

Content
According to a myth, the ancient Greek philosopher Democrit dissected animals, because he was in search of the seat of the soul. Current neuroscientists use neuroimaging techniques like functional magnetic-resonance-tomography in order to localize cognitive and emotional qualities in the brain. Between these two dates lies a history of 2500 years, in which the relationship between the mind and the brain has been defined in various ways. Starting with ancient and medieval theories, the lecture will have its focus on modern theories from the nineteenth century onward. I will discuss essential issues in the history of the neurosciences such as localization theories, the neuron doctrine, reflex theory, theories of emotions, neurocybernetics and the importance of visualizing the brain and its parts, but I will also include works of art and literature.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>851-0337-00L</td>
<td>African Intellectual and Artistic Presence: From “Négritude” to the “Ateliers de la pensée”</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>F. Sarr</td>
</tr>
</tbody>
</table>

Abstract
The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities.

Objective
We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational aspects of Africa and the contemporary world.

Content
The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities; this from the Nègritude movement (1930s) to the Dakar Thought Workshops ("Ateliers de la pensée", 2016). We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

<table>
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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0499-00L</td>
<td>Globalization – Theories, Concepts, Aspects</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>S. M. Scheuzger</td>
</tr>
</tbody>
</table>

Abstract
The course offers an introduction into theories of globalization and presents key concepts of the analysis of processes of globalization. Among the many aspects of globalization – which is dealt with in its historical dimensions – the course focuses on the interactions between these processes on the one hand and technical and scientific developments on the other.

Objective
A) The students know central theories of globalization. B) They are familiar with different concepts of analysis of processes of globalization and are able to assess them. C) They are able to reflect, on this basis, on the interconnectedness between technical and scientific developments and processes of global entanglements.

Content

Once upon a time there was natural law, the foundation of sexual relations between two people of different genders, in order to procreate.

This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

851-0101-72L The Modern City and Cultural Criticism. The "Knowledge of Life" in Reform Movements 1880-1933

Abstract
Rapid industrialisation, urbanisation and the unique sociopolitical conditions of 19th century Germany led, from 1880 onwards, to radical changes in the socio-cultural and political life of the country. This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

Objective
This lecture is part of the "Science in Perspective" course programme: students will learn about the precursors of today's calls for reform and alternative concepts which propagated the "back-to-nature" lifestyle around the 1900s.

Content
The rapid industrialisation, mechanisation and urbanisation of 19th century Europe gave rise to a whole new set of challenges and problems in cities. From 1880 onwards, the unique sociopolitical conditions in Germany resulted in anti-urban and cultural criticism by parts of the bourgeoisie and academic youth. This lecture focuses on the theory and aesthetic practice of belief in the "Life reform movement".

Literature
The reading list includes literary texts and discursive texts, amongst others, from Gustav Landauer, Erich Mühsam, Else Lasker-Schüler, Paul Scheerbart, Heinrich and Julius Hart, Rudolf Steiner, Sebastian Kneipp, Max Bircher-Benner, Theodor Hertzka, Franz Oppenheimer, Ebenezer Howard, Theodor Goecke, Hermann Muthesius, Karl Schmidt-Hellerau, Bruno Taut, Gustav Wyneken, Wassily Kandinsky, Ludwig Klages, Emile Jaques-Dalcroze, Walter Benjamin, Martin Buber. Furthermore, we will discuss creative contributions from E. M. Lilien and Fidus (pseudonym Hugo Höppener).

851-0125-65L A Sampler of Histories and Philosophies of Mathematics

Abstract
This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective
The course aims to:
1. To introduce students to the historiography of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices.

851-0197-00L Medieval and Early Modern Science and Philosophy

Abstract
The course analyses the evolution of the relation between science and philosophy during the Middle Age and the Early Modern Period.

Objective
The course aims to:
- to introduce students to the philosophical dimension of science
- to develop a critical understanding of scientific notions
- to acquire skills in order to read and comment on scientific texts written in the past ages

Content
This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

851-0082-00L Literature and the Knowledge of the Social

Abstract
The course investigates the evolution of the relation between science and philosophy during the Middle Age and the Early Modern Period.

Objective
The course aims to:
- to introduce students to the philosophical dimension of science
- to develop a critical understanding of scientific notions
- to acquire skills in order to read and comment on scientific texts written in the past ages

Content
This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.
At the beginning of the 19th century, the social sciences established themselves and oriented themselves towards the natural sciences and mathematics, their knowledge models and research methods in order to produce empirically proven knowledge of the social. Terms such as 'social physics' (Auguste Comte) or 'mass psychology' bear witness to this. Conspicuously, in the course of this "scientization of the social" (Lutz Raphael), reference is often made to literature, which is recognized as an essential instrument of social science practice. E.g., in the debate on the so-called social question at the beginning of the 19th century, literature is employed to make the discourse on poverty more scientific by making individual fates which are unrepresentable by statistics the object of theory formation. Thus Karl Marx refers to Eugène Sue's 'The Secrets of Paris' in his interpretation of the social. The relevance of literature for the production of knowledge of the social has recently been demonstrated by the sociologist Luc Boltanski in his monograph "Mysteries & Conspiracies. Detective Stories, Spy Novels and the Making of Modern Societies" (2012) which showed how the way in which crime and spy novels problematize reality has shaped the historical development of the humanities and social sciences.

The course is based on the assumption that this combination of literature and the social sciences has always made statements about the premises of the differentiation of literature and science, of the humanities and the natural sciences and their different practices and research goals (keyword: "Science in Perspective"). The integration of literature in the production of knowledge of the social is relevant to the question of the conditions of possibility of a scientifically secured knowledge of the social for several reasons: It permits, firstly, the question of the extent to which the humanities have shaped the supposedly scientific-mathematically oriented social sciences in questions of methodology, epistemic interest and theory formation of knowledge of the social. This question has remained recognizable until presently, in projects such as SHAPE-ID, which is domiciled at the ETH and other European Universities and is dedicated to the integration of the arts as well as the historical and social sciences in trans- and interdisciplinary research, with the purpose tackling societal challenges. It has, secondly, become aesthetically productive and has led to the genesis of new poetic means that, on the one hand, reflect the specifics of social science knowledge production by literary means, but, on the other, claim to produce evaluable data on the social. Examples of this are primarily crime and spy novels, but also travelogues and urban novels or genres such as the social science survey, which share with the natural sciences methods of sampling, observation, documentation and experimentation.

**Objective**

- Overview of social science in its connection to literature from the 1830s to the present day
- Overview of popular literary genres that are relevant for social science
- Reflecting and historicising the question of the epistemic status of literature and the aestheticization of knowledge.
- Reflecting and historicising the question of the relevance of literature for the humanities and natural sciences

**Content**

- Reflection of knowledge production and methods
- At the beginning of the 19th century, the social sciences established themselves and oriented themselves towards the natural sciences and mathematics, their knowledge models and research methods in order to produce empirically proven knowledge of the social. Terms such as 'social physics' (Auguste Comte) or 'mass psychology' bear witness to this. Conspicuously, in the course of this "scientization of the social" (Lutz Raphael), reference is often made to literature, which is recognized as an essential instrument of social science practice. E.g., in the debate on the so-called social question at the beginning of the 19th century, literature is employed to make the discourse on poverty more scientific by making individual fates which are unrepresentable by statistics the object of theory formation. Thus Karl Marx refers to Eugène Sue's 'The Secrets of Paris' in his interpretation of the social. The relevance of literature for the production of knowledge of the social has recently been demonstrated by the sociologist Luc Boltanski in his monograph "Mysteries & Conspiracies. Detective Stories, Spy Novels and the Making of Modern Societies" (2012) which showed how the way in which crime and spy novels problematize reality has shaped the historical development of the humanities and social sciences. The course is based on the assumption that this combination of literature and the social sciences has always made statements about the premises of the differentiation of literature and science, of the humanities and the natural sciences and their different practices and research goals (keyword: "Science in Perspective")). The integration of literature in the production of knowledge of the social is relevant to the question of the conditions of possibility of a scientifically secured knowledge of the social for several reasons: It permits, firstly, the question of the extent to which the humanities have shaped the supposedly scientific-mathematically oriented social sciences in questions of methodology, epistemic interest and theory formation of knowledge of the social. This question has remained recognizable until presently, in projects such as SHAPE-ID, which is domiciled at the ETH and other European Universities and is dedicated to the integration of the arts as well as the historical and social sciences in trans- and interdisciplinary research, with the purpose tackling societal challenges. It has, secondly, become aesthetically productive and has led to the genesis of new poetic means that, on the one hand, reflect the specifics of social science knowledge production by literary means, but, on the other, claim to produce evaluable data on the social. Examples of this are primarily crime and spy novels, but also travelogues and urban novels or genres such as the social science survey, which share with the natural sciences methods of sampling, observation, documentation and experimentation.

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**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | not assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | not assessed |
| Domain C - Social Competencies | Media and Digital Technologies | not assessed |
| Domain D - Personal Competencies | Communication | not assessed |
| | Sensitivity to Diversity | not assessed |
| | Negotiation | not assessed |
| | Adaptability and Flexibility | not assessed |
| | Creative Thinking | not assessed |
| | Critical Thinking | not assessed |

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**Objective**

- Not a few members of the elites argue that important issues in democracy like policies against climate change, free trade agreements, or the specifics of social science knowledge production by literary means, but, on the other, claim to produce evaluable data on the social.

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**Objective**

- Participants should become familiar with basic approaches to central problems in environmental ethics.
- The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).
- Another focus will be to clarify the concept of "climate justice".
- The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

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**Preparatory Literature**

Gender and Science
C. L. Blaser

Mandatory and further reading will be listed on the course plan that is made available as from the first session.

3 credits

The philosopher Günther Anders characterized his monograph "Die Antiquiertheit des Menschen" as a "philosophical anthropology in the service of a cultural and ethical renewal", with a focus on the specific intersections with the sciences taught at ETH.

Gender and Science

The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.

Students will thereby be encouraged to learn from concrete examples rather than abstract theory. The goal is for students to understand how to apply concepts and methods of gender studies to particular disciplines. A mid-term discussion session and end-term assignment will provide students the opportunity to critically reflect on how these questions are relevant for their own academic practices.

Seminars

851-0020-00L Gender and Science W 2 credits 2V C. L. Blaser, M. Lichtenberg

Abstract
A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series asks whether one single model of modernization prevailed on the "Old Continent" or whether we need to differentiate regionally. A special focus lies on the Swiss experience.

Objective
At the end of this lecture course, students can: (a) highlight the most important changes in the "long nineteenth century" in Europe (b) explain their long-term effects; and (c) relate these changes to global developments today.

Content
The thematic foci include: Industrialization on the British Isles, urban growth in Switzerland, the difficult road to democracy in Germany, and French individualism.

Lecture notes
PowerPoint Slides and references will be made available in digital form during the course of the semester.

Prerequisites / notice
This lecture series does not build upon specific previous knowledge by the students.

851-0019-00L

Abstract
This lecture series offers an introduction to the relationship between gender and science, with a focus on the specific intersections with the sciences taught at ETH.

Objective
This lecture series is designed to acquaint students from all levels and departments with the various ways in which gender perspectives matter for specific scientific disciplines, as well as for science in general. Students will learn to recognize and analyze the specific ways in which scientific theories and methods are gendered, and how this connects to their own scientific disciplines.

Content
There is agreement across academic disciplines today that gender influences and structures the production of knowledge and that scientific knowledge production in turn shapes gender notions. Even within "hard" sciences such as mathematics, physics, engineering, etc., gender is a significant factor in determining what counts as "objective" knowledge, who can know it, what kind of knowledge is produced, or how this knowledge is acquired and justified. Feminist research aims to reveal how dominant conceptions of science and knowledge practices disadvantage women*, and other subordinate groups, with the goal of reforming these practices. An important part of feminist critique is to show that such efforts substantially improve the overall quality of research.

The semester will start with an introductory lecture acquainting students with research questions in the field of Gender and Science by summarizing its key concepts and methods. It will then continue as a series of weekly guest lectures, given by scholars from different scientific disciplines, that provide accessible insights into the intersection between gender studies and the guest lecturer's research field.

Students will thereby be encouraged to learn from concrete examples rather than abstract theory. The goal is for students to understand how to apply concepts and methods of gender studies to particular disciplines. A mid-term discussion session and end-term assignment will provide students the opportunity to critically reflect on how these questions are relevant for their own academic practices.

Abstract
This course introduces students to foundational texts that led to the emergence of the environment as a subject of scientific importance, and shaped its relevance to society. Above all, the course seeks to give confidence and raise enthusiasm among students to read more widely around the broad subject of environment and management both during the course and beyond.

Objective
The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.

Content
The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The lecturer will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session.

Presentation of the text requires the students to prepare by, for example: summarizing its key concepts and methods, and identifying issues of particular personal interest and resonance. Considering the impact of the text at the time of publication, and its importance now. Evaluating the text from the perspective of our current societal and environmental position.

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

Abstract
The specific texts selected for discussion will vary, but examples include:

- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Lovelock (1979) Gaia: A New look at life on Earth
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

851-0430-00L Günther Anders: The Antiquity of Man W 3 credits 2S M. Hagner

Abstract
The philosopher Günther Anders characterized his monograph "Die Antiquiertheit des Menschen" as a "philosophical anthropology in the age of technocracy". Andorra had written his book under the impression of the atom bomb, the computer and visual mass media. Today, the book is more relevant than ever: What is the role of human beings in the Anthropocene?

Objective
The goal of this seminar is a close reading of Günther Anders's "Die Antiquiertheit des Menschen", reflect its main topics and hypotheses and discuss their relevance for our time.

Content
The basic material for this seminar will be the monograph „Die Antiquiertheit des Menschen” (https://www.chbeck.de/antiquiertheit-menschen-bd-i-ueber-seele-zeitalter-zweiten-industriellen-revolution/product/23611879/). Reading this book and other texts will lead to a special focus lies on the Swiss experience.

French individualism.

851-0175-00L  Images of the Human  W  3 credits  2G  J. L. Gastaldi

Abstract
This seminar explores the multiple transformations of the conception of the "human" in the face of the current scientific, social and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences.

Objective
By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

Content
The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the "human". In this way, computer science and technology have join other scientific disciplines having experienced in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre's activities, the focus will be on challenges in the context of recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

851-0421-00L  Sapiens: A Reading Course  W  3 credits  2S  N. Guettler

Abstract
Yuval Noah Harari's "Sapiens" is the most successful historical book of recent years. The seminar examines the text from a history of science perspective: What kind of sources does it rely on? What type of history is being written here? And in what tradition does "Sapiens" represent a popular non-fiction book?

Objective
In the course of the seminar, the students develop the competence to deal with the original text and the research literature on the history of anthropology, science and technology in a critical and historically thoughtful way. In doing so, they practise navigating independently through historical literature by means of smaller research tasks.

Content
The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the history of mankind by reading "Sapiens". In addition to studying and critically discussing the original text, the students explore significant scientific and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of the underlying narratives and popular science genres that inform "Sapiens".

851-0168-00L  Aristotle’s Lecture on Physics  W  3 credits  2S  M. Hampe

Abstract
Aristotle’s lecture on physics is a theory of movement. But his concept of movement or change (kinesis) is much more general than the modern one, that applies only to changes of place by bodies. This is far reaching consequences. Aristotle’s physics can therefore be interpreted as a general theory of natural processes.

Objective
Students should develop a clear understanding of a complex pre-modern theory of nature.

Content
Aristotle’s lecture on physics is a theory of movement. But his concept of movement or change (kinesis) is much more general than the modern one, that applies only to changes of place by bodies. This is far reaching consequences. Aristotle’s physics can therefore be interpreted as a general theory of natural processes.

851-0162-00L  Philosophy of Physics  W  3 credits  3S  M. Hampe, R. Wallyn

Number of participants limited to 50.
Abstract

Close reading of and reflection about selected texts from physicists (e.g. C.F: Weizsäcker, Wilczek, Suskis) on the philosophical problems and consequences of their work.

Objective

Participants should develop a clear view of the epistemological foundations of their work and its consequences for philosophy of science and philosophy of nature.

Content

Newton's opus magnum of 1687 is still called a philosophy of nature: "Philosophiae Naturalis Principia Mathematica". The separation of physics from philosophy is new, and institutionally executed only in the 19th century. Since then the experiment is not a philosophical method and mathematical symbolization not part of the languages of philosophy anymore. But although the subjects were divided methodically they stayed in contact via their content. This can be seen in the reflexions of physicists like C. F. v. Weizsächer, Frank Wilczek or Leonard Suskis, who were all concerned with epistemological questions and topics related to the philosophy of science and philosophy of nature. The seminar is devoted to these reflexions and will ask in what relation the philosophy of physicists stands to the physics of their time. We will discuss problems of the unity of physics, of emerging laws and of the beauty or ugliness of the physical universe resp. the theories about it.

Literature

see moodle

Prerequisites / notice

The course follows the concept of an "inverted classroom". A prerequisite is that the relevant texts have been read prior to the lecture. The assistants will give support.

851-0087-00L Knowledge and Practice in Philosophy of War

Does not take place this semester.

Abstract

In the seminar we read classical texts from the field of 'philosophy of war'. Due to today's technological advancements and ecological problems, we will also discuss contemporary conceptions of war such as lethal autonomous weapons and climate change. Important questions that arise are: Is the concept of war only applicable to human society? Is there a difference between politics and nature?

Objective

Students learn about the different types of arguments and conceptions in philosophical texts and their historical context. They should learn to understand the descriptive and critical value of texts in regard to the topic of war.

851-0536-00L Technology and the Environment – On Course for Collision?

Abstract

Technology has been both the cause and the solution of many environmental problems. Motor vehicle emissions contribute to climate change. Apps are supposed to help us minimizing our CO2 footprint. This course examines which politics, social relations, economic interests, environmental changes, and forms of engineering have conditioned which types and consequences of technology in modern history.

Objective

Students will discuss primary and secondary sources about the relationship between technology and the environment since the nineteenth century. They will learn to analyze argumentative strategies, divergent perspectives, and consequences and to write precisely and trenchantly about technology and the environment in society.

851-0081-00L Artificial Intelligence. Interdisciplinary Perspectives

Abstract

In the last 50 years, research on artificial intelligence (AI) has repeatedly boom but failed to deliver on its great promises. In the last decade, however, especially the deep learning approach has achieved remarkable results This eLearning-seminar will discuss epistemological, but also ethical and political aspects of these recent developments in interdisciplinary perspective.

Objective

Students will learn to reflect on one of the most attention-grabbing technologies of recent years in terms of its epistemological basis and social impact.

Content

In the last 50 years, research on artificial intelligence (AI) has repeatedly boom but failed to deliver on its great promises. In the last decade, however, especially the deep learning approach has achieved remarkable results and is already applied in many contexts. Since this approach breaks with assumptions of the older symbolic approaches of AI research, a new philosophical discussion is needed. Therefore, the interdisciplinary seminar will start from the classical philosophical debate, which was shaped by thinkers like Herbert Dreyfus and John Searle and focused on the concept of the rule following, in order to confront it with the newer state of research, its data driven approach and the concept of learning. We will discuss the consequences and challenges of these new approaches in AI for their theoretical and philosophical reflection. In a second step, the seminar will discuss not only epistemological, but also ethical and political aspects of the recent developments in AI in interdisciplinary perspectives.

Prerequisites / notice

The seminar will be conducted as an eLearning event in cooperation with LMU Munich.

851-0300-86L Max Frisch: Experiments of Storytelling

Abstract

This seminar provides an insight into the poetic and narrative procedures of Max Frisch's prose writing. Frisch's writing can be essentially understood as experimenting with a new mode of narration which takes on epistemological functions and treats themes of existential philosophy.

Objective

1) Overview of the prose writings by Max Frisch; 2) insight in the poetic and narrative procedures of Max Frisch's prose writings; 3) understanding of the novels of Max Frisch as epistemological and philosophical projects.

Content

"Narrative: but how?", asked Max Frisch in his diary. In his prose the answer to this question is definitely troublesome since it transcends the classic form and function of narrative. His novels - from Stiller (1954), Homo faber (1957), Mein Name sei Gantenbein (1964) to his late prose Montauk (1975) and Der Mensch erscheint im Holozän (1979) - but also his journals (including 1950) can be essentially understood as experiments of a new mode of narration, which implies a multiple perspective. Not only is the narrative performed according to a formal technique, but, at the same time, it takes on epistemological and existential philosophical functions. The purpose is epistemological since this type of narrative strives to generate knowledge; it is existential philosophical as soon as characters such as Stiller and Gantenbein prove to be myth-maniac inventors of their self. Out of necessity, or playfully, they perform (other) identities. "Ich probiere Geschichten an wie Kleider", thus Gantenbein and again Montauk. Narrative, play, disguise, and (self)deception become anthropological practices; even as "Gier nach Geschichten" (craving for stories) they become an elementary effort of human life.

Literature

Litteratur zur Anschaffung:
Max Frisch. Romane, Erzählungen, Tagebücher.
Erschienen: 17.11.2008
Suhrkamp Quarto 0
Broschur, 1782 Seiten
ISBN: 978-3-518-42005-8

851-0301-11L The Unconditionality of Knowledge: Faust in European Literature

Abstract

His unconditional desire for knowledge made "Faust" the symbolic figure of the modern period. Since the Renaissance, a rich Faust-literature, ranging from Marlowe, Goethe, and up to Thomas Mann, has portrayed the highly conflictual emancipation of knowledge from theology as well as the self-assertion of a modern knowledge of nature and the human being.
Learning objectives: Faust is one of the most dazzling figures in European literature and cultural history. A pact with the devil, magic, sexual desire, power and knowledge, these are the great taboos of the medieval world, which, in 1500, the graduated theologian set out to dismantle. Through this demonstrative gesture of hubris, he became the much-disputed hero of the modern period. Since the "Historia von Johann Fausten" (1587), the wide range of Faust-literature also depicts the highly conflictual emancipation from theological knowledge in favor of an unconditional knowledge of nature and the human being that hides itself behind disciplines such as medicine, astrology and magic. Faust was thereby not only transformed into the epitome of the fortuneteller, he also became the cipher for the risky undertaking of modern knowledge as such, to which he then spectacularly fell victim in an experiment. Consequently, the course's treatment of this subject matter in the literature since the early modern period will center on the question of knowledge as it is negotiated through the Faust-figure. Initially, we shall take a look at examples from the early modern period (apart from the Faust-book from 1587, among others the drama version by Christopher Marlowe, 1589). Then we shall move on to new editions around 1800, which highlight the modernity of this norm-transcending and boundary-breaking knowledge paradigm (among others Goethe's Faust). Finally, we shall discuss Faust-figures of the 20th century, such as Friedrich Murnau's Faust movie (1926). Thomas Mann's novel, "Doktor Faustus", written in exile in 1947, or Klaus Mann's "Mephisto" (1936).

Semester Report

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<tr>
<th>Number</th>
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<th>Hours</th>
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<tr>
<td>862-0006-00L</td>
<td>Semester Report</td>
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Semester Paper

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<tr>
<td>862-0008-26L</td>
<td>Term Paper History of Technology (HS 2021)</td>
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<tr>
<td>862-0009-25L</td>
<td>Term Paper in Science of Knowledge (HS 2021)</td>
<td>W</td>
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</table>
### Major Courses

#### Essays

In each subject of the master reading lists are handed out. The books on these lists are the subject of the tutorials one has to attend with the teachers that are named in the Leitfaden. In three subjects essays are to be written on works from these lists.

<table>
<thead>
<tr>
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<td><strong>Abstract</strong></td>
<td>This essay is the outcome of an individual teaching and learning process during several terms and draws upon representative books and articles in history of technology. It has to consider the state of the art in the field.</td>
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<td>862-0023-00L</td>
<td>Essay on Readings in Science Research (HS)</td>
<td>W</td>
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<td>862-0027-00L</td>
<td>Essay on Readings in Practical Philosophy (HS)</td>
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<td>862-0029-00L</td>
<td>Essay on Readings in Literature and Culture (HS)</td>
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<td>862-0031-00L</td>
<td>Essay on Readings in History of the Modern World (HS)</td>
<td>W</td>
<td>10 credits</td>
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<tr>
<td>862-0035-00L</td>
<td>Essay on Readings in History and Philosophie of Mathematical Sciences (HS)</td>
<td>W</td>
<td>10 credits</td>
<td>21A</td>
<td>Lecturers</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>One-to-one supervisions form the basis for an essay covering the paradigmatic texts studied over several semesters. This essay should also take recent research into account. The instructor will work one-to-one with the student to hone the skills and fundamental topics that are relevant for the Master's thesis.</td>
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The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research. This fortnightly colloquium provides a forum for PhD students and postdoctoral researchers to present and discuss their current work. Half of the slots are reserved for presentations by invited external scholars.

**Research Colloquium**

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
862-0004-13L | Research Colloquium Philosophy for Master Students and PhD (HS 2021) | W | 2 credits | 1K | R. Wagner, M. Hampe, L. Wingert

**Abstract**
Ph.D. students, post docs, members of staff, and senior colleagues from other philosophy departments will report on their work in progress. Furthermore, promising new philosophical articles and parts of new philosophical books will be studied.

**Objective**
Ideas and arguments dealing with systematic problems especially in epistemology, ethics, political philosophy, and the philosophy of mind will be scrutinized and elaborated.


**Abstract**
The forntightly colloquium provides a forum for PhD students and postdoctoral researchers to present and discuss their current work. Half of the slots are reserved for presentations by invited external scholars.

**Prerequisites / notice**
Information about dates and program:
http://www.gmw.ethz.ch/studium.html

862-0088-09L | Research Colloquium Science Studies (HS 2021) | W | 2 credits | 1K | M. Hagner

**Abstract**
This colloquium is devoted to the introduction into the theory and practice of scientific work. The schedule can be found on the institute’s website - http://www.wiss.ethz.ch/en/teaching/

**Objective**
This colloquium is devoted to the introduction into the theory and practice of scientific work.

862-0089-09L | Advanced Colloquium in Literary Studies (HS 2021) | W | 2 credits | 1K | A. Kilcher

**Abstract**
The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

**Objective**
The colloquium addresses advanced and graduate students. First, it offers participants the opportunity to present their own research projects (work in progress); and, second, it provides a most fruitful space to discuss methodological, theoretical and systematic complex issues.

851-0551-18L | Colloquium for Master and PhD Students History of Technology (HS 2021) | W | 2 credits | 1K | D. Gugerli

**Abstract**
Colloquium for master and doctoral students preparing a thesis in the history of technology.

**Objective**
Goals: to identify, discuss, and resolve methodological problems that emerge while elaborating a master or doctoral thesis.

**Prerequisites / notice**
Anmeldung bei Rachele Delucchi (rachele.delucchi@history.gess.ethz.ch). Siehe fürs Programm auch: www.tg.ethz.ch

**Master's Thesis**
The work on the master-thesis is supervised by one of the teachers that are allowed to offer tutorials for it, named in the Leitfaden.

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
862-0500-00L | Master's Thesis | O | 30 credits | 64D | Supervisors

**Objective**
A student is only permitted to commence the Master thesis if:
- the Bachelor degree programme has been completed
- any additional requirements for admission to the degree programme have been fulfilled
- all credits have been acquired in the categories basic courses and major courses and at least 6 credits have been acquired in the category research colloquium

**Abstract**
The Master's thesis gives a thorough historical, philological or philosophical analysis of a topic related to the experimental or formal sciences or to technology. It incorporates the relevant research literature on this topic as well as first attempts at original research.

**Objective**
The master thesis gives a thorough historical, philological or philosophical analysis of a topic related to the experimental or formal sciences or to technology. It incorporates the relevant research literature on this topic as well as first attempts at original research.
**History and Philosophy of Knowledge Master - Key for Type**

<table>
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<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td></td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
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<td>Dr</td>
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**Key for Hours**

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

**ECTS**

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
### Military Studies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>853-0037-01L</td>
<td>Military Psychology and Pedagogy I (Without Exercises)</td>
<td>Z</td>
<td>3 credits</td>
<td>2V</td>
<td>H. Annen</td>
</tr>
</tbody>
</table>

**Abstract**
Examine the fundamentals of the two sciences and establish links with military life. Discuss various schools of thought in psychology and focus on content and process theories of motivation. Explore characteristics of pedagogical thinking and discuss the values of military education with reference to the young adult serving in the armed forces.

**Objective**
- Becoming acquainted with basic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences

**Content**
Overall, the objective is to become acquainted with the basics of both scientific areas and to make references to military practice. Military psychology is a branch of applied psychology; consequently selected aspects of psychological principles will be covered. Military pedagogy hasn't yet established itself firmly as an independent scientific discipline, it nevertheless can draw on a deep-seated tradition in Switzerland. Thus, the great importance that has been attached to the discussion of education in Swiss society and academia will be taken into account.

**Subjects**
- History of military psychology
- Psychological images of humanity (psychoanalysis, behaviourism, behavioural biology, humanistic psychology, cognitivism)
- Motivational theories
- Defence-, service-, operational- and combat motivation
- Swiss military pedagogy
- Education as defining feature of pedagogic thinking and acting

**Literature**
- Annen, H., Steiger, R. & Zwyygart, U.: Gemeinsam zum Ziel, Huber, Frauenfeld 2004 (provided as pdf)
- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)

The lecture is supported by a virtual learning environment containing relevant documents (presentations and texts) and information to further literature.

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Leadership and Responsibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Military History I (without Exercises)</th>
<th>Z</th>
<th>3 credits</th>
<th>2V</th>
<th>A. Wettstein, T. Cubito, M. Olsansky</th>
</tr>
</thead>
</table>

**Abstract**
The purpose of the lecture is to outline the development of the armed forces (assets regarding manpower, technology and armament), the concepts of warfare and the actual warfare in the 19th and 20th century.

**Objective**
- Distinguish between military history as a subject and historiography as a way of describing events;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).

**Content**
The lecture first examines the bases of the science of military history. It focuses on how military history developed from war history, on specific similarities and differences between military history and general historiography, the different ways of dealing with history in Switzerland, Germany, France and in the Anglo-Saxon cultural area (different approaches) as well as on institutions which deal with military history such as universities, military academies, national and international commissions and associations etc.

The lecture is structured along the lines of the concept of “Military Revolution” and starts with the formation of modern, European armed forces after the Oranian Army reform in the 17th century. Based on the “Military Revolution” approach, the lecture examines the structural changes regarding the armed forces and the development of warfare from the 18th to the 20th century. Special emphasis will be put on how the battlefield was revolutionized due to the Napoleonic wars, the industrialization in the 19th century, the First World War, the mechanization and totalization during the Second World War and the period of the Cold War.

**Literature**

<table>
<thead>
<tr>
<th>Number</th>
<th>Strategic Studies I</th>
<th>Z</th>
<th>3 credits</th>
<th>2V</th>
<th>M. Mantovani</th>
</tr>
</thead>
</table>

**Abstract**
The lecture series treats high-impact strategic theory from antiquity to the present. The participants know how the understanding of strategy has evolved over time. They understand the interplay of strategy's basic components: ends, ways, means. They know the most important classics of strategy and war theory, especially against their specific historical background. Based on the analysis of historical and contemporary examples, they are aware of the mismatch between declaration and implementation of any given strategy. They are capable of analyzing original texts and modern scholarly works in the field of strategic studies.

**Objective**
The two-term lecture series treats classic texts of strategic studies from antiquity to the present. Term 1 covers the theories up until roughly 1900, term 2 treats the theories ever since. Theories are considered classic if they were prominent in their respective times and if they enjoyed a strong reception thereafter, be it in literature, in academic debates or as guidelines for action (doctrine). Each out of some 50 theories is discussed in three steps: historical context, core elements and reception.

**Literature**
- Peter Paret, Makers of Modern Strategy. From Machiavelli to the Nuclear Age, Princeton 1986.

**Prerequisites / notice**
The lecture is held in German.
Passive knowledge of English and French are required.
The semester program of the course is divided into 14 modules of 90 minutes each, which combine lecture (Teaching of analytical competencies) and exercise (application by means of concrete case studies).

<table>
<thead>
<tr>
<th>Domain</th>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Military Sociology I</td>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td>Objective</td>
<td></td>
<td>Techniques and Technologies</td>
<td>Decision-making</td>
<td>Customer Orientation</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td>Media and Digital Technologies</td>
<td>Problem-solving</td>
<td>Leadership and Responsibility</td>
<td>Integrity and Work Ethics</td>
</tr>
<tr>
<td>Literature</td>
<td></td>
<td>Project Management</td>
<td>Self-presentation and Social Influence</td>
<td>Self-awareness and Self-reflection</td>
<td>Self-direction and Self-management</td>
</tr>
<tr>
<td>Taught competencies</td>
<td></td>
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</tbody>
</table>

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

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

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

**Military Sociology I**

**Z 3 credits 2V**

**M. M. Keupp**

**Abstract**
Beside of the most important terms of sociology, demographic changes and the related value and structure change will be analysed. The second part focuses on organizational sociology. Thirdly, the course examines to which extent armed forces can be considered as organizations like any other and to which extent they constitute a special case from an organizational and normative point of view.

**Objective**
Recognize and explain current changes (social change) in modern society (individualisation, pluralisation); describe demographic changes in Switzerland; explain the structures of societies; define issues and fields of research in modern military sociology and explain the foundations of organisational sociology; explain the military in terms of organisational sociology and identify specific traits of the military as an organisation.

**Content**
Societal change; organizations as societal phenomena; aims, structures, environments of organizations; specifics of the military as an organization; impacts of technological and societal changes on the armed forces in modern societies.

**Literature**
A reader with a set of texts will be handed out.

**Defense Economics I**

**Z 3 credits 2V**

**M. M. Keupp**

**Abstract**
In terms of structure and content, the event follows the lecturer’s book "Militärökonomie" (Military Economics), which is available in two language versions:

- German language: ISBN 978-3-658-06146-3

**Objective**
* Recognizing parallels and contrasts between business and military thinking;
* Understand the link between institutions, human action and economic results.

**Content**
The semester program of the course is divided into 14 modules of 90 minutes each, which combine lecture (teaching of analytical techniques) and exercise (application by means of concrete case studies).

The contents correspond to sections 1 to 2.2.5 of the above book. The following will be discussed:

1. fundamental military economic problems including historical introduction to the topic
2. the institutional foundations of a military organisation
3. the modern military as a planned economy system
4. actors and stakeholders in the system

**Lecture notes**
Lecture slides are given to the participants before the first lecture. In addition, the above mentioned book will be handed over to the participants. Participants of the lecture who are not professional officer candidates are requested to obtain the book from the library or bookstore.

**Literature**


**Prerequisites / notice**
none.

**Leadership I**

**853-0033-00L**

**For BA Public Policy and DAS Military Scineces only.**

**Z 3 credits 2V**

**F. Kernic, F. Demont, M. Holenweger**

**Abstract**
The lectures "Leadership I" (WS) and "Leadership II" (SS) have been designed as a two-semester lecture series, but may also be followed independently of one another or in reverse order. "Leadership I" covers the following fields: leadership basics, leadership theories and leadership styles, the concept of leadership responsibility and the role of communication in practical leadership.

**Objective**
The aim of this lecture is to give students an introductory overview of relevant topics regarding leadership research and practice, thus enabling them to gain a deeper understanding of the leadership phenomenon. Students should understand different concepts of leadership in the complex interaction between individuals, groups, organisation, context and situation. They should be informed about the evolution of the understanding of mankind in relation to working processes and its impact on organizations and the understanding of leadership theory in the past 100 years. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations. They should recognize the fundamental importance of communication in leadership situations and receive input which enables them to communicate adequately in specific situations.
### Further Courses (no SiP-courses)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0370-00L</td>
<td>Didactic Basics for Student Teaching Assistants</td>
<td>Z</td>
<td>1 credit</td>
<td>1S</td>
<td>S. Pedrocchi, B. Volk</td>
</tr>
</tbody>
</table>

**Abstract**
The course "Didactic Basics for Student Teaching Assistants" enhances Student Teaching Assistants (Student TAs) to develop knowledge, capability and confidence to effectively plan and teach courses and exercises. Participants get trained to think critically about students’ learning and create learning situations in which students are actively engaged.

**Objective**
In this course, Student Teaching Assistants will:
- reflect on their approach to teaching as well as their attitude towards teaching.
- understand the basics of teaching and learning in the context of their subject.
- consciously design the introduction of their course as well as the introduction of single teaching units.
- apply classroom assessment techniques to measure the current status of their students.
- develop a didactic concept according to the learning objectives.
- conduct interactive sequences as learning activities.
- give and get feedback from peers and self-reflect on their teaching practice.
- feel confident to use methods for active teaching in their classes.

**Content**
The online course provides a range of relevant topics for developing teaching competencies of Student Teaching Assistants:

- Overview about how learning works. Based on these fundamentals of learning participants reflect on their role as Student TAs to feel comfortable in their new role as a teacher.
- Plan an own lesson by introducing a class and locate it in the larger topic (methods: portal and informative introduction).
- Develop learning activities in order to activate students (active learning methods).
- Giving and also getting feedback. The participants integrate this topic also in their lesson plan.

While working through the online course, Student TAs have the chance to reflect, exchange ideas with peers and plan their own teaching accordingly so that they feel confident in their role.

**Prerequisites / notice**
Self-paced online course: https://moodle-app2.let.ethz.ch/course/view.php?id=15127

**Consolidation Workshops in November** (dates will be announced in the online course at the beginning of the semester)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0371-00L</td>
<td>Coaching Students</td>
<td>Z</td>
<td>1 credit</td>
<td>1S</td>
<td>B. Volk, R. P. Haas, S. Pedrocchi</td>
</tr>
</tbody>
</table>

**Abstract**
The course "Coaching Students" enhances Student Teaching Assistants (Student TAs) in their role as student coaches to develop basic knowledge about coaching methodology and the mindset of a coach.

**Objective**
In this course, Student Teaching Assistants will:
- understand the basics of coaching and the role as student coaches.
- develop the mindset of a coach and reflect on their attitude towards guiding student learning processes (individuals and teams).
- acquire coaching skills and build knowledge and know-how about coaching methods.
- analyse learning scenarios and team situations by developing and verifying hypotheses.
- design the coaching session and feel confident to use coaching methods.
- give and get feedback from peers and self-reflect on their coaching practice.

**Content**
The course starts with a kick-off meeting in the first lessons to provide an overview of the role as student coaches and the following online phase. The online phase with 6 live sessions will provide a range of relevant topics for developing coaching competencies:

- Overview about coaching: Based on this, participants reflect on their role as student coaches in order to develop the mindset of a coach, including the differences and similarities of coaching individuals vs. teams.
- Introduction into coaching methodology, incl. the differences and similarities of coaching individuals vs. teams.
- Coaching skills training: active listening, asking questions and giving/getting feedback.

While working through the online course, Student TAs have the chance to reflect, exchange ideas with peers and plan their own coaching accordingly so that they will feel confident in their role as student coaches.

**Prerequisites / notice**
This course (also the synchronous activities) takes place ONLINE!

Kick-off on 4.10.2021 (16:15-18h)
followed by five double lessons with in-class activities (skills training):
- 11.10.2021 (16:15-18h)
- 18.10.2021 (16:15-18h)
- 25.10.2021 (16:15-18h)
- 1.11.2021 (16:15-18h)
- 8.11.2021 (16:15-18h)

Two optional double lessons:
- 15.11.2021 (16:15-18h)
- 22.11.2021 (16:15-18h)

All double lessons start at 4.15pm and finish by 6pm.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0372-00L</td>
<td>Ready, Set, Go!</td>
<td>Z</td>
<td>0 credits</td>
<td>K. Brown, B. Volk</td>
<td></td>
</tr>
</tbody>
</table>

This course is open to Student Teaching Assistants (students with teaching duties in exercises, practicals etc.) from all departments and chairs.

**Objective**
- Reflecting on your teaching role
- Finding out about your students
- Introducing your course and class
- Planning student engagement
Learning to Teach

This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities.

Abstract

This course imparts a variety of teaching skills which will help Doctoral Teaching Assistants with their teaching tasks.

Objective

In this course Doctoral Teaching Assistants will:

- discuss learning science and teaching techniques with peers.
- design the introduction of their course/lecture/exercise class.
- develop learning activities according to learning objectives.
- practice classroom assessment techniques in order to measure student learning.
- engage in peer feedback in order to improve own teaching.

Content

We will meet for the kick-off meeting online on the 1st of October 2021 from 1-3 pm. You will get detailed information together with the invitation email in the first week of the semester. The self-paced online phase, where you work through 6 modules in the Moodle course page will end by the 17th of November 2021. We will meet on the 23/24 or 26 of November 21 for the Consolidation workshop. You will find more information on the course page in Moodle.

Prerequisites / notice

This programme is designed for ETH Doctoral Teaching Assistants with current teaching responsibilities (exercises, excursions, supervision of practicals, lectures, etc.) or those who will assume teaching tasks in the semester following the programme. No previous teacher training is required.

Specialized Continuing Education

Special internal ETH courses offered by LET and the Teaching Specialists.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>999-9999-99L</td>
<td>EduApp Course</td>
<td>E-</td>
<td>0</td>
<td>V+1U</td>
<td>B. Volk</td>
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</table>

Humanities, Social and Political Sciences (General Courses) - Key for Type

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<th>Key for Type</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
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<td>O</td>
<td>Compulsory</td>
<td></td>
<td></td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<td>V</td>
<td>lecture</td>
<td></td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>S</td>
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<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<td></td>
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</tbody>
</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
At the end of this lecture course, students can: (a) highlight the most important changes in the "long nineteenth century" in Europe (b) explain their long-term effects; and (c) relate these changes to global developments today.

This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

The course combines lecture and tutorial. Active participation in class through short presentations and working papers is required. This requires 1-2 hours of preparation time per week in addition to class attendance.

Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>853-0725-00L</td>
<td>History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>H. Fischer-Tine</td>
</tr>
<tr>
<td>Abstract</td>
<td>A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series asks whether one single model of modernization prevailed on the 'Old Continent' or whether we need to differentiate regionally. A special focus lies on the Swiss experience.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>At the end of this lecture course, students can: (a) highlight the most important changes in the &quot;long nineteenth century&quot; in Europe (b) explain their long-term effects; and (c) relate these changes to global developments today.</td>
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</tr>
<tr>
<td>Content</td>
<td>The thematic foci include: Industrialization on the British Isles, urban growth in Switzerland, the difficult road to democracy in Germany, and French individualism.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Power Point Slides and references will be made available in digital form during the course of the semester.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Mandatory and further reading will be listed on the course plan that is made available as from the first session.</td>
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</tr>
<tr>
<td>Prerequisites</td>
<td>This lecture series does not build upon specific previous knowledge by the students.</td>
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<td></td>
<td>/ notice</td>
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</tr>
<tr>
<td>851-0105-00L</td>
<td>Background Knowledge Arabic World on Refugees and Science 1933-1945</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>U. Göksen</td>
</tr>
<tr>
<td>Abstract</td>
<td>This lecture will discuss important topics of the Arab culture involving concepts relating to history, the role of literature, sciences and religion, concepts of 'the West', meaning of education, understanding of culture as well as current concepts and discourses relevant at the sociocultural level.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Teaching about epistemic contents relating to the Arabic world that constitute modern Arabs' self understanding and are relevant for adequate behavior in practically dealing with the Arabic world. What basic knowledge about 'their' culture are Arabs taught? What educational goals are pursued? What is the relationship between the West?</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>The topics that are discussed on the basis of a scientifically critical approach are concepts and understandings of history, the role of literature, sciences and religion, concepts of the West and relationship with the West, the role of education, understanding of culture and cultural refinement, current concepts and discourses relevant at the sociocultural level.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites</td>
<td>/ notice</td>
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<tr>
<td>851-0105-88L</td>
<td>National Socialist Persecution, International Politics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>T. Avermaete</td>
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<tr>
<td>Abstract</td>
<td>The course discusses the development of National Socialist persecution policy, the reactions of democratic states to the persecution of the Jews and the role of science in the Nazi regime.</td>
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<tr>
<td>Objective</td>
<td>The students are able to distinguish the phases of persecution and know various models to explain how the Holocaust came about. They can situate Swiss refugee policy in an international context. In their engagement with science under National Socialism, they develop an awareness of the socio-political responsibility of science.</td>
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<tr>
<td>Content</td>
<td>The &quot;Nazis&quot; and the &quot;Holocaust&quot; are omnipresent in politics and entertainment industry - often combined with a lack of historical knowledge. The students learn about the logic of radicalization from exclusion to extermination. The reaction of selected states to the persecution of Jews will enable them to recognise the challenge the Nazi regime posed to Western democracies and to place Swiss refugee policy in an international context.</td>
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<td>Prerequisites</td>
<td>The course combines lecture and tutorial. Active participation in class through short presentations and working papers is required. This requires 1-2 hours of preparation time per week in addition to class attendance.</td>
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### Type A: Enhancement of Reflection Competence

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>052-0801-00L</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>T. Avermaete</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.</td>
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<tr>
<td>Objective</td>
<td>The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students' future design work.</td>
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<tr>
<td>Content</td>
<td>In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:</td>
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<td></td>
<td>01. The History and Theory of the City as Project</td>
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<td>02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus</td>
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<td>03: The Idea of the Polis: Rome, Greece and Beyond</td>
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<td>04: The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi</td>
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<td>05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles</td>
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<td>06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization</td>
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<td>07: The City of Labor: Company Towns as Cross-Cultural Phenomenon</td>
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<td>09: Garden Cities of Tomorrow: From the Global North to the Global South and Back Again</td>
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<td>010: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham</td>
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<td></td>
<td>011: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid</td>
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</table>

There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).

Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

### 851-0011-00L

#### The Body in Global History

**Objective**

Students learn the history of the body from mid-eighteenth century onwards through examples taken from the multidisciplinary scholarship on the body with a special, albeit not exclusive, focus on colonial and postcolonial contexts. More specifically, students are sensitized to the historical and cultural variabilities of the human body that challenge scientific understandings of it as an unchanging biological entity. Adopting a humanities perspective on topics like anatomy and surgery, the treatment of the insane, sexuality, physical culture, eugemics, and body productivity, the course looks at shifting attitudes to body health and fitness and the ways these have been shaped by considerations of gender, race, and class as well as by socioeconomic circumstances of modernity. It considers how bodies have historically concerned governments who have classified different (sections of) populations as ‘fit’ or ‘unfit’ to be members of a certain community. The ‘soukère’ approach of the course allows to consider the continuities and changes in terms of scientific epistemologies and practices regarding the body. In doing so, debated contemporary issues such as assisted reproductive technologies and wearable systems of surveillance of the worker fatigue in the workplace are discussed.

The course is structured thematically, adopts a multidisciplinary approach, and uses academic texts as well as concrete examples. It intends to a) enable STEM students to develop new perspectives on their core subjects by bringing them in dialogue with the themes dealt with by raising ethical questions; b) familiarise students in general with major shifts in the field of the recent scholarship on the body and make them mindful of the multiple ways in which understanding the body and its relationship with culture and power can help think critically of the present we live in.

**Literature**


### 851-0175-00L

#### Images of the Human

**Objective**

By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

**Notice**

The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the “human”. In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre’s activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

**Literature**


### 851-0422-00L

#### A Modern Utopia: Science and Visions of the Future

**Objective**

This course explores how science and technoscience produced utopian or dystopian visions of the future in historical context, assessing how new developments in the physical, natural, and economic sciences since c.1880 have shaped possible “futures” in Western thought.

**Notice**

This course equips students with the skills to assess how scientific ideas diffused broader ideas of present and future societies in the West since industrialization. Students will be able to compare and contrast distinct developments in the relationship between science and society, identify key trends in thinking about the future, and explain how science informed ethical and social questions.

**Literature**


### 851-0421-00L

#### Sapiens: A Reading Course

**Objective**

In the course of the seminar, the students develop the competence to deal with the original text and the research literature on the history of anthropology, science and technoscience in a critical and historically thoughtful way. In doing so, they practise navigating independently through historical literature by means of smaller research tasks.

**Notice**

The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the history of mankind by reading “Sapiens”. In addition to studying and critically discussing the original text, the students explore significant scientific and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of the underlying narratives and popular science genres that inform “Sapiens”.

**Literature**


### 851-0527-00L

#### Introduction to the History of Technology: Concepts, and Current Debates

**Objective**

This course seeks to provide a critical introduction to the issues, methods, and selected areas of research in the history of technology.

**Notice**

History of technology investigates technological developments that arise in specific historical contexts. These developments are perceived by social groups or entire societies as a means of social change and ultimately find use or are forgotten. The questions that history of technology poses derive from the technological and social change that are a product of contemporary orientation and historiography; current historiographical methods provide the tools for answering these questions.

**Literature**

The Modern City and Cultural Criticism. The Yemen Republic is the result of the unification in 1990 of two former states: The Yemen Arab Republic (North Yemen) and the People's Democratic Republic of Yemen (South Yemen). The country's history and its former units have been marred with civil wars, poverty and epidemic corruption.

Globalization – Theories, Concepts, Aspects

The course offers an introduction into theories of globalization and presents key concepts of the analysis of processes of globalization. Among the many aspects of globalization – which is dealt with in its historical dimensions – the course focuses on the interactions between these processes on the one hand and technical and scientific developments on the other.

Objective

A) The students know central theories of globalization. B) They are familiar with different concepts of analysis of processes of globalization and are able to assess them. C) They are able to reflect, on this basis, on the interconnectedness between technical and scientific developments and processes of global entanglements.

Content


Prerequisites / notice

Die Vorlesung findet im Format eines "Flipped Classroom" statt. Der Inhalt der Sitzungen wird wöchentlich in einer 45-minütigen Zoom-Aufnahme digital zugänglich gemacht. Im Präsenzunterricht werden die Sitzungsinhalte dann gemeinsam diskutiert. Um bessere Diskussionen zu ermöglichen, finden die Präsenzsitzzungen nur alle zwei Wochen, dafür aber 90 Minuten lang statt und haben jeweils die Themen von zwei Vorlesungssitzungen zum Gegenstand.

The Modern City and Cultural Criticism. The "Knowledge of Life" in Reform Movements 1880-1930

Rapid industrialisation, urbanisation and the unique sociopolitical conditions of 19th century Germany led, from 1880 onwards, to radical cultural critique and calls for reform of parts of the bourgeoisie and youth. This lecture focuses on the theory and aesthetic practice of a wide range of reform movements, the so-called "Lebensreform" (life reform movement).

Objective

The lecture is part of the "Science in Perspective" course programme: students will learn about the precursors of today's calls for reform and alternative concepts which propagated the "back-to-nature" lifestyle around the 1900s.

Content

The rapid industrialisation, mechanisation and urbanisation of 19th century Europe gave rise to a whole new set of challenges and problems in cities. From 1880 onwards, the unique sociopolitical conditions in Germany resulted in anti-urban and cultural criticism by parts of the bourgeoisie and academic youth, culminating in the idea that the fanatical belief in progress would end in disaster. Consequently, a wide array of reform movements sprang up, focusing on medical hygiene and socio-political, ideological, religious and spiritual concepts, which were intended to heal the mind and body. These movements were a whole German and Swiss phenomenon and summarised under the term "Lebensreform" which also encompassed naturopathy, dress reforms, naturopathy, health food and vegetarianism, youth and women's movements, sexual liberation and intentional communities, organic farming, land reform, cooperative/free economy/garden city movement, nature conservation and homeland protection, progressive education and homeland protection, progressive education and housing movement, art education and Dalcroze eurhythmics, expressive dance, theatre reforms, regional literature and art, anthroposphy, the emergence of German-Geeman/German Christian religious communities, religious socialism and the Jewish renaissance.

This movement was clearly politically diverse, and attracted all manner of advocates, for example, those with social anarchist, jingoistic or anti-Semitic beliefs. What made them kindred spirits was their rather negative experience of modernisation: their fantasies about the era merely confirmed that existing perceptions of the human existence (Dasein) were obsolete. Amongst the fantasies was, as described by Gert Mattenklott, the idea of a dramatic shift in current thinking and the creation of a new world, the emergence of a new mankind that embodied the characteristics of youth, and a new community. Strong dichotomies like light and darkness, hot and cold, the fears of dehumanisation and a propensity for vegetarianism were also typical of life reforms.

The lecture is part of the "Science in Perspective" course programme: students will learn about the precursors of today's calls for reform and alternative concepts which propagated the "back-to-nature" lifestyle around the 1900s. Some of the key concepts used then are unknown today or have been disavowed due to exploitation by the totalitarian regimes of the 20th century. Nevertheless, some of the original topics and objectives have once again become contemporary topics of discussion due to the debate about the future of society, the future of mankind and the whole planet. Historization of present-day concepts is the condition on which plans for a possible future can be compared with previous attempts and experiences, and to identify alternatives and potential impasses, and provide objective evidence for debate.

Literature

The reading list includes literary texts and discursive texts, amongst others, from Gustav Landauer, Erich Mühsam, Else Lasker-Schüler, Paul Scheerbart, Heinrich and Julius Hart, Rudolf Steiner, Sebastian Kneipp, Max Bircher-Benner, Theodor Hertzka, Franz Oppenheimer, Ebener Goede Howard, Theodor Geckoe, Hermann Muthesius, bourgeois and socialist, and 45th-century authors. Ludwig Klages, Emile Jaques-Dalcroze, Walter Benjamin, Martin Buber. Furthermore, we will discuss creative contributions from E. M. Lilien and Fidus (pseudonym Hugo Höppener).

Yemen: A Failed State?

Is Yemen a failed state? The Yemen Republic is the result of the unification in 1990 of two former states: The Yemen Arab Republic (North Yemen) and the People's Democratic Republic of Yemen (South Yemen). The country's history and its former units have been marred with civil wars, poverty and epidemic corruption.

Objective

1. Examine the concept of failed state within the International relations literature. 2. Take a closer look at Yemen(s) political history(ies), its political and social structures, and power dynamics. 3. Introduce the concept of the 'cunning state' and its exploitation of the discourse of failed state

Content

This seminar looks at the concept of failed states and how useful it can be in describing the situation in a country like Yemen. It will also take a closer look at Yemen(s) political history(ies) and its political and social structures. Students are expected to write a paper and make a presentation.
Abstract
This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective
The course aims at:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection on the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students’ horizons to the plurality of mathematical cultures and practices

851-0107-00L Science and the Public: A Problem of Mediation that the Media Have to Solve? W 2 credits 1S U. J. Wenzel

Abstract
Scientific knowledge is often provisional; it is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of (scientific) knowledge. This is shown by the Corona pandemic, but not only by it.

Objective
Gaining insights into the relationship between the sciences, the public and the media, into their historical development and current problems.

Content
The feuilleton of the «Frankfurter Allgemeine Zeitung» of 27 June 2000 has gone down in the annals of recent media history. The last sequences of the fully mapped human genetic code were printed on six large-format pages: the letters A, G, C and T in various combinations and sequences - a «readable» but incomprehensible jumble of letters. What at the time was astounding journalistic coup and met with excitement as well as head shaking can (also) be read as an allegory of the tense relationship between science and the public. What can, what should, what do «laymen» want to know and understand from scientific findings? Scientific knowledge is often provisional; it is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of (scientific) knowledge. This is shown by the Corona pandemic, but not only by it. How can science journalism, how can scientists deal with this problem? Do the natural sciences, medicine and technology differ from the humanities and social sciences in terms of «comprehensibility» and public awareness?

These questions will be explored on some excursions into recent and also older media, scientific and cultural history.

851-0537-00L Architectures of Knowledge: Infrastructures of the University W 3 credits 2S N. Bredella

Abstract
The seminar explores interrelations between the architecture of the university and forms of knowledge production. The emphasis is on the end of the 20th century, when digital infrastructures increasingly merged with the spatial constellation of the lecture hall, laboratory and library. We will discuss the discursive spaces that condition the reading, thinking and perception of knowledge.

Objective
Using positions from the history of technology, science and architecture, the seminar will discuss the spatial-technical ensembles of the university and their significance to the production and circulation of knowledge. Case studies provide insights into the overlapping spatial and digital infrastructures that shaped ideas of research and teaching at the end of the 20th century.

Content
The seminar deals with the spatial-technical organization and communication forms of the university. Of particular interest is how, in the context of digitization, digital infrastructures overlap and intertwine with built space and determine the self-understanding of the sciences. At its core the course asks you to identify how teaching and research methods correlate with the social, material and spatial structures of the university.

851-0101-56L From Cotton to Cocaine: Commodities That Made History (c.1700-1950) W 3 credits 2V H. Fischer-Tiné

Abstract
Each session focuses on a particular commodity and explores how its production, trade and consumption was entangled with important political, social and cultural developments. Taken together, the case studies (ranging from agricultural crops, via chemically produced drugs to mechanical marvels such as the gramophone) provide a picture of major global transformations in the past 300 years.

Objective
On one level, the course aims to familiarise students with a currently much debated approach to the writing of global history, namely the history of commodities. Each case study is used to deepen the participants’ understanding of complex historical development by seemingly simple stories in a global frame. Thus, for instance, the session on sugar explores plantation economies in the Caribbean and the transatlantic slave trade as well as shifting patterns of diet and consumption in Europe. The session on rubber focuses on botanical expeditions in Latin America, the deployment of Chinese coolies on Malaysian Rubber farms and the rise of the automobile mass production in the USA. By linking the familiar to the unfamiliar and ‘exotic’ the inter-cultural sensitivity of the students will be enhanced.

On a second level, the analysis and understanding of these complex interconnections, it is hoped, will help students to get a more nuanced understanding of the historical process that is currently referred to as ‘globalisation’ and overcome the eurocentric perspective that still structures many scholarly and media writings on this topic.

851-0008-00L Ban on Alcohol and Science: A Global History of Prohibition 1918–1939 W 3 credits 2S E. Biçer-Deveci

Abstract
The seminar deals with an overview on anti-alcohol campaigns since late 19th century. The focus is on prohibition in the interwar period in different regions. The role of scientific experts in the emergence of prohibition will be discussed from a global historical perspective. Formation of international networks and process of knowledge production on the issue of alcohol are subjects of analysis.

Objective
The reconstruction of the development of prohibitionist regimes helps to understand the process of national institution formations, for example health societies. Participants analyze interactions between science, international relations and change of social political context in the process of knowledge production and in the definition of daily life norms on drinking habits.

Literature

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<th>Lecturers</th>
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<tr>
<td>851-0337-00L African Intellectual and Artistic Presence: From “Nègritude” to the “Ateliers de la pensée”</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>F. Sarr</td>
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Abstract
The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities.

Objective
We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

Content
The objective of this seminar is to provide a critical overview of contemporary African thought as it is expressed in literature, philosophical discourse, social sciences, and the humanities; this from the Nègritude movement (1930s) to the Dakar Thought Workshops (“Ateliers de la pensée”, 2016). We will explore the questions posed by contemporary thinkers from the African continent and its diasporas; and see to what extent these shed light on the political, cultural and civilizational issues of Africa and the contemporary world.

851-0336-00L Eros: Athens, Rome, Vienna, Paris | W | 3 | 2V | G. Sissa |

Abstract
Once upon a time there was natural law; the foundation of sexual relations between two people of different genders, in order to procreate. Today, new rights and new forms of life are profoundly transforming both naturalness and purpose.

Objective
This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.
Content
Once upon a time there was natural law, the foundation of sexual relations between two people of different genders, in order to procreate. Today, new rights and new forms of life are profoundly transforming both naturalness and purpose. Everything seems to change suddenly. However, the long-term history shows us a great variety of erotic cultures, from ancient Greece to the Roman world and then to Christian and multicultural Europe. This course presents some crucial moments of this distant past, in which knowledge, practices and representations have shaped disparate experiences of desire, pleasure and the body. Challenges for a fluid present, ideas for the near future.

851-0300-86L
Max Frisch: Experiments of Storytelling

Abstract
This seminar provides an insight into the poetic and narrative procedures of Max Frisch’s prose writing. Frisch’s writing can be essentially understood as experimenting with a new mode of narration which takes on epistemological functions and treats themes of existential philosophy.

Objective
1) Overview of the prose writings by Max Frisch; 2) insight in the poetic and narrative procedures of Max Frisch’s prose writing; 3) understanding of the development of Max Frisch’s prose writing as epistemological and philosophical projects.

Content
“Narrative: but how?”, asked Max Frisch in his diary. In his prose the answer to this question is definitely troublesome since it transcends the classic form and function of narrative. His novels - from Stiller (1954), Homo faber (1957), Mein Name sei Gantenbein (1964) to his late prose Montauk (1975) and Der Mensch erscheinung im Holozän (1979) - but also his journals (including 1950) can be essentially understood as experiments of a new mode of narration, which implies a multiple perspective. Not only is the narrative performed according to a formal technique, but, at the same time, it takes on epistemological and existential philosophical functions. The purpose is epistemological since this type of narrative strives to generate knowledge; it is existential philosophical as soon as characters such as Stiller and Gantenbein prove to be myth-maniac inventors of their self. Out of necessity, or playfully, they perform (other) identities. "Ich probiere Geschichten an wie Kleder", thus Gantenbein and again Montauk. Narrative, play, disguise, and (self)deception become anthropological practices; even as "Gier nach Geschichten" (craving for stories) they become an elementary effort of human life.

Literature
Literator zur Anschaffung:
Max Frisch, Romane, Erzählungen, Tagebücher.
Erschienen: 17.11.2008
Suhkamp Quarto 0
Broschur, 1782 Seiten
ISBN: 978-3-518-42005-8

851-0301-11L
The Unconditionality of Knowledge: Faust in European Literature

Abstract
His unconditional desire for knowledge made "Faust" the symbolic figure of the modern period. Since the Renaissance, a rich Faust-literature, ranging from Marlowe, Goethe, and up to Thomas Mann, has portrayed the highly conflictual emancipation of knowledge from theology as well as the self-knowledge of nature and the human being.

Objective
Learning objectives: Faust is one of the most dazzling figures in European literature and cultural history. A pact with the devil, magic, sexual desire, power and knowledge, these are the top taboos of the medieval world, which, in 1500, the educated theologian set out to dismantle. Through this demonstrative gesture of hubris, he became the much-disputed hero of the modern period. Since the "Historia von Johann Fausten" (1587), the wide range of Faust-literature also depicts the highly conflictual emancipation from theological knowledge in favor of an unconditional knowledge of nature and the human being that hides itself behind disciplines such as medicine, astrology and magic. Faust was thereby not only transformed into the epitome of the fortuneteller, he also became the cipher for the risky undertaking of modern knowledge as such, to which he then spectacularly fell victim in an experiment. Consequently, the course's treatment of this subject matter in the literature since the early modern period will center on the question of knowledge as it is negotiated through the Faust-figure. Initially, we shall take a look at examples from the early modern period (apart from the Faust-book from 1587, among others the drama version by Christopher Marlowe, 1589). Then we shall move on to new editions around 1800, which highlight the modernity of this norm-transcending and boundary-breaking knowledge paradigm (among others Goethe’s Faust). Finally, we shall discuss Faust-figures of the 20th century, such as Friedrich Murnau's Faust movie (1926), Thomas Mann's novel, "Doktor Faustus", written in exile in 1947, or Klaus Mann's "Mephisto" (1936).

851-0082-00L
Literature and the Knowledge of the Social

Abstract
The course shows to what extent "literature" from the 19th to the 21st century and the - often empirical - sciences of the social are mutually dependent. It is based on theoretical social science texts as well as literary genres that are used to model knowledge, primarily crime novels and spy novels, but also travelogues and city novels or genres such as the social science survey.

Objective
Overview of of social science in its connection to literature from the 1830s to the present day
Overview of popular literary genres that are relevant for social science
Reflecting and historicising the question of the epistemic status of literature and the aestheticization of knowledge.
Reflecting and historicising the question of the relevance of literature for the humanities and natural sciences
Reflection of knowledge production and methods

Content
At the beginning of the 19th century, the social sciences established themselves and oriented themselves towards the natural sciences and mathematics, their knowledge models and research methods in order to produce empirically proven knowledge of the social. Terms such as 'social physics' (Auguste Comte) or 'mass psychology' bear witness to this. Conspicuously, in the course of this "scientization of the social" (Lutz Raphael), reference is often made to literature, which is recognized as an essential instrument of social science practice. E.g., in the debate on the so-called social question at the beginning of the 19th century, literature is employed to make the discourse on poverty more scientific by making individual fates which are unrepresentable by statistics the object of theory formation. Thus Karl Marx refers to Eugène Sue's 'The Secrets of Paris' in his interpretation of the social. The relevance of literature for the production of knowledge of the social has recently been demonstrated by the sociologist Luc Boltanski in his monograph "Mysteries & Conspiracies. Detective Stories, Spy Novels and the Making of Modern Societies" (2012) which showed how the way in which crime and spy novels problematize reality has shaped the historical development of the humanities and social sciences.

The course is based on the assumption that this combination of literature and the social sciences has always made statements about the premises of the differentiation of literature and science, of the humanities and the natural sciences and their different practices and research goals (keyword: "Science in Perspective"). The integration of literature in the production of knowledge of the social is relevant to the question of the conditions of possibility of a scientifically secured knowledge of the social for several reasons: It permits, firstly, the question of the extent to which the humanities have shaped the supposedly scientific-mathematically oriented social sciences in questions of methodology, epistemic interest and theory formation of knowledge of the social. This question has remained recognizable until presently, in projects such as SHAPE-ID, which is domiciled at the ETH and other European Universities and is dedicated to the integration of the arts as well as the historical and social sciences in trans- and interdisciplinary research, with the purpose tackling societal challenges. It has, secondly, become aesthetically productive and has led to the genesis of new poetic means that, on the one hand, reflect the specifics of social science knowledge production by literary means, but, on the other, claim to produce evaluable data on the social. Examples of this are primarily crime and spy novels, but also travelogues and urban novels or genres such as the social science survey, which share with the natural sciences methods of sampling, observation, documentation and experimentation.

Autumn Semester 2021
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In this course we will examine the two sides of writing technology. On the one hand, we will direct our attention to that most conspicuous writing technology of our world: the coded symbols of digital computers. On the other hand, we will consider a set of fictional works that explore the forms, uses, and implications of such technology in writing. We will also regularly jump back and forth between the two sides of the issue, literally and figuratively re-coding literary writing in the language of information theory to see what is lost—and what is gained—in translation.

The tutelary spirit of our course is the American mathematician Claude Shannon, the author of The Mathematical Theory of Communication and the founder of information theory. But Shannon’s own muse was Edgar Allen Poe, whose 1843 story, ’The Gold-Bug,’ inspired Shannon to regard language as a probabilistic system susceptible to mathematical analysis. A passionate reader of Poe, Shannon was also fascinated by the vertiginous vocabulary of James Joyce’s novels, whose exceptional information content he contrasted with C.K. Ogden’s proposal for “Basic English,” a simplified, ‘universal’ language consisting of only 850 English words. We will examine all of these sources as well as others so that we may reconnect the key terms of Shannon’s theory (“information,” “code,” “message,” “translation,” etc.) with the literary traditions that—at least in part—inspired him.

Over the course of the semester, we will turn from specific writing technologies to more capacious logics of control: writing technologies ’writ large.’ After looking at the machine languages and feedback mechanisms that underwrite the mid-century field of cybernetics, we will read excerpts from Samuel Beckett’s experimental novel, Watt, and examine how it imagines the intersection of human cognition with digital logic. Watt, Beckett’s hapless protagonist, obliges us to reexamine the programs we habitually follow and to ask ourselves, ‘watt’ has digital communications technology done to how we live and how we think?

### Economics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0626-01L</td>
<td>International Aid and Development</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>K. Harttgen, I. Günther</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 60</td>
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<td>Prerequisites: Basic knowledge of economics</td>
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<td></td>
<td>Abstract</td>
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<td></td>
<td>The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid.</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Students are able to critically discuss the various aid instruments of bi- and multilateral donors and NGOs.</td>
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<td></td>
<td>Literature</td>
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<tr>
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<td>Articles and book abstracts will be uploaded to a course website.</td>
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<tr>
<td>851-0609-06L</td>
<td>Governing the Energy Transition</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>T. Schmidt, N. Schmid, S. Sewerin</td>
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<tr>
<td></td>
<td>Primarily suited for Master and PhD level.</td>
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<tr>
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<td>Abstract</td>
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<td>This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socio-economic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.</td>
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<td>Objective</td>
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<td></td>
<td>- To gain an overview of the history of the transition of large technical systems</td>
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<td>- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions</td>
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<td></td>
<td>- To gain knowledge on the role of policy and politics in energy transitions</td>
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<td></td>
<td>Content</td>
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<td>Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.</td>
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<td>This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of policy and policy change in governing the energy transition, considering the role of political actors, institutions and policy feedback.</td>
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<td>Lecture notes</td>
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<tr>
<td></td>
<td>Slides and reading material will be made available via moodle.ethz.ch (only for registered students).</td>
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<tr>
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<td>Literature</td>
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<td>A reading list will be provided via moodle.ethz.ch at the beginning of the semester.</td>
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<td>Prerequisites / notice</td>
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<td>This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science &amp; Technology; MSc Environmental Sciences; MSc Management, Technology &amp; Economics; MSc Science, Technology &amp; Policy; ETH &amp; UZH PhD programmes.</td>
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</table>
### Content
Introduction to environmental management / environmental management systems, energy and material flows; economical and ecological problems in industry; characterisation of an enterprise (incl. management handbook); structur and contents of an environmental management system; overview on the ISO 14001 ff. series; methods for environmental evaluation and assessment; integrated management systems; planning methodology and life-cycle-design design; planning exampl

### Lecture notes
Information about environmental management and environmental management systems will be provided by a CD or mail.

### Literature
A list with literatures and links will be provided.

### Prerequisites / notice
Delivery of a case study, worked out in groups. Language: Teaching in English on request.

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>363-1027-00L</td>
<td>Introduction to Health Economics and Policy</td>
<td>2</td>
<td>V</td>
<td>C. Waibel</td>
</tr>
</tbody>
</table>

### Abstract
Health expenditures constitute about 10% of GDP in OECD countries. Extensive government intervention is a typical feature in health markets. Risk factors to health have been changing with growing importance of lifestyle factors such as smoking, obesity and lack of physical activity. This course gives an introduction to the economic concepts and empirical findings in health economics.

### Objective
Introduce students without prior economic background to the main concepts of health economics and policy to enhance students understanding of how health care institutions and markets function.

Please note that we will apply basic economic concepts to health care markets. Hence, master students with an economic background have to expect that a large share of the concepts will overlap with their previous courses. However, they are, of course, welcome to join the course.

### Content
The course gives an introduction to the economic concepts and empirical findings in health economics to enhance students understanding of how health care institutions and markets function. Motivated by the fact that health care markets are designed differently across countries, this course looks at the challenges in regulating health care markets. First, two important decisions of individuals will be analyzed: What types and amount of personal health care services does an individual demand? How much will health insurance coverage be purchased? In the second part, the supply side of health care markets will be discussed. What are the financial incentives of physicians, and how do these influence physicians' treatment choices? What does it mean and imply that a physician is an agent for a patient? The choices made by societies about how health care services are financed and about the types of organizations that supply health care will be addressed in the third part. One important choice is whether a country will rely on public financing of personal health care services or encourage private health insurance markets. How could and should a public health insurance system be designed? The advantages and disadvantages of the alternatives will be discussed to provide a framework for analyzing specific types of health care systems.

### Literature
Jay Bhattacharya, Timothy Hyde, Peter Tu, "Health Economics", Palgrave Macmillan.

### Prerequisites / notice
Although we apply basic economic concepts to health care questions, students should be aware that this course requires some mathematical skills in terms of maximization problems.

Please be prepared that this course might (partially) be run via zoom, depending on the situation.

<table>
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<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>363-1050-00L</td>
<td>Simulation of Negotiations</td>
<td>3</td>
<td>V</td>
<td>M. Ambühl, A. Knobel</td>
</tr>
</tbody>
</table>

### Abstract
The Global Studies Institute (University of Geneva) is organizing a simulation seminar on Nagorno-Karabakh in collaboration with MGIMO Moscow (TBC) and the Chair of Negotiation and Conflict Management (ETHZ).

### Objective
Students will have the possibility to participate in simulated diplomatic negotiations and to analyse and assess the negotiation logic behind the situation. During the course, they should gain insight into the negotiations between Armenia, Azerbaijan, and the international community, as well as negotiation techniques in general.

### Limited number of participants.
Students who wish to register for this course have to apply no later than 18 September. Please send your application to Andreas Knobel: aknobel@ethz.ch, additionally register in mystudies (technical note for the registration: All registered students will initially be placed on a waiting list).
In the lectures, students will be provided with basic information related to Nagorno-Karabakh. The historical, military, economic and political dimensions, including the various treaties and existing agreements and their evolution will be analyzed. Students will as well participate in an introduction on negotiation techniques, particularly on the negotiation engineering approach. On the basis of the comprehensive analysis, negotiation scenarios will be developed and subsequently tested during a two-day simulation exercise. The simulation exercise will be prepared with the help of experienced negotiators and experts.

The simulation exercise is intended for Masters degree and PhD students. The course will be taught in English. The project is headed by Prof. Micheline Calmy-Rey and Prof. Nicolas Levrat, Global Studies Institute, University of Geneva.

Students who wish to register for this course have to apply no later than 18 September 2021. Please send your (brief) application with your background and motivation to Andreas Knobel: aknobel@ethz.ch, additionally register in mystudies (Technical note for the registration: All registered students will initially be placed on a waiting list.)

The homepage for this course with more information is located at: https://necom.ethz.ch/education/simulation-of-negotiations.html.

Students from ETH Zurich and MGIMO will participate in the seminar sessions via video conferencing. They will go to Geneva for the simulation exercise on 2 and 3 December 2021.

There will be two exercise sessions (see separate course 363-1050-01L).

Date | Time | Topic (Location)  
--- | --- | ---  
28 September | 10:15-12:00 | Introduction (VC)  
5 October | 9:15-12:00 | Introduction to Negotiation Engineering (VC)  
12 October | 10:15-12:00 | Scenarii and random drawing of teams (VC)  
19 October | 10:15-12:00 | TBA (VC)  
26 October | 10:15-12:00 | TBA (VC)  
2 November | 10:15-12:00 | TBA (VC)  
9 November | No session (Reading week, but see exercises)  
16 November | 10:15-12:00 | TBA (VC)  
23 November | 10:15-12:00 | Preparation (VC)  
2-3 December | 08:00-17:00 | Simulation (GE)  
7 December | 10:15-12:00 | Debriefing (VC)  

<table>
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<tr>
<th>Prerequisites / notice</th>
<th>Evaluation</th>
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</table>
I. Active participation in class (50%)  
1. Attend all seminar sessions either in person or via video conference and actively participate in discussions.  
2. Participate in person in the two-day simulation exercise (19-20 November 2021).  

II. Texts to be submitted before, during and after the simulation (50%)  
1. Before the simulation: Prepare a 4-5 page summary of your group’s negotiating mandate, including a description of the positions of all the parties (group evaluation).  
2. During the simulation: Draft and present an introductory and final statement (group evaluation).  
3. After the simulation: Prepare a report on the negotiation outcomes to the organization, state or region you represent (3-4 pages) and a press release (max. 1 page). The report and press release are individually evaluated.

<table>
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<tr>
<th>363-0387-00L</th>
<th>Corporate Sustainability</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>V. Hoffmann, C. Bening-Bach, N. U. Blum, J. Meuer</th>
</tr>
</thead>
</table>
Abstract | The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food. |  
Objective | Students - assess the limits and the potential of corporate sustainability for sustainable development - develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method. - recognize and realize opportunities through team work for corporate sustainability in a business environment - present strategic recommendations in teams with different output formats (tv-style debate, consultancy pitch, technology model walk-through, argumentation video) |  
Content | In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share their insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester. |  
Lecture notes | http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html |  
Literature | Presentation slides will be made available on moodle prior to lectures. |  
Prerequisites / notice | TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points. |  

<table>
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<tr>
<th>363-0503-00L</th>
<th>Principles of Microeconomics</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>M. Filippini</th>
</tr>
</thead>
</table>
Abstract | The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution. |
The learning objectives of the course are:

(1) Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and describe firm and consumer behaviour. (4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:


The book can also be used for the course 'Principles of Macroeconomics' (Sturm)

Complementary:


For students taking only the course 'Principles of Macroeconomics' there is a shorter version of the same book:


The book can also be used for the course 'Principles of Microeconomics' (Filippini).
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

363-0561-00L Financial Market Risks

W 3 credits 2G D. Sornette

Abstract
I aim to introduce students to the concepts and tools of modern finance and to make them understand the limits of these tools, and the many problems met by the theory in practice. I will put this course in the context of the on-going financial crises in the US, Europe, Japan and China, which provide fantastic opportunities to make the students question the status quo and develop novel solutions.

Objective
The course explains the key concepts and mechanisms of financial economics, their depth and then stresses how and why the theories and models fail and how this is impacting investment strategies and even a global view of citizenship, given the present developing crises in the US since 2007 and in Europe since 2010.

- Development of the concepts and tools to understand these risks and master them.

- Working knowledge of the main concepts and tools in finance (Portfolio theory, asset pricing, options, real options, bonds, interest rates, inflation, exchange rates)

- Strong emphasis on challenging assumptions and developing a systemic understanding of financial markets and their many dimensional risks
1- The Financial Crises: what is really happening? Historical perspective and what can be expected in the next decade(s). Bubbles and crashes. The illusion of the perpetual money machine.

2- Risks in financial markets
- What is risk?
- Measuring risks of financial assets
- Introduction to three different concepts of probability
- History of financial markets, diversification, market risks

3- Introduction to financial risks and its management.
- Relationship between risk and return
- Portfolio theory: the concept of diversification and optimal allocation
- How to price assets: the Capital Asset Pricing Model
- How to price assets: the Arbitrage Pricing Theory, the factor models and beyond

4- Financial markets: role and efficiency
- What is an efficient market?
- Financial markets as valuation engines: exogeneity versus endogeneity (reflexivity)
- Deviations from efficiency, puzzles and anomalies in the financial markets
- Financial bubbles, crashes, systemic instabilities

5- An introduction to Options and derivatives
- Calls, Puts and Shares and other derivatives
- Financial alchemy with options (options are building blocks of any possible cash flow)
- Determination of option value; concept of risk hedging

6- Valuation and using options
- A first simple option valuation model
- The Binomial method for valuing options
- The Black-scholes model and formula
- Practical examples and implementation
- Realized prices deviate from these theories: volatility smile and real option trading
- How to imperfectly hedge with real markets?

7- Real options
- The value of follow-on investment opportunities
- The timing option
- The abandonment option
- Flexible production
- Conceptual aspects and extensions

8- Government bonds and their valuation
- Relationship between bonds and interest rates
- Real and nominal rates of interest
- Term structure and yields to maturity
- Explaining the term structure
- Different models of the term structure

9- Managing international risks
- The foreign exchange market
- Relations between exchanges rates and interest rates, inflation, and other economic variables
- Hedging currency risks
- Currency speculation
- Exchange risk and international investment decisions

Lecture notes
Lecture slides will be available on the site of the lecture

Abstract
The course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through their cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.

Objective
The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management and develop strategies to harness the value of user-developed ideas and contributions for firms and other organizations.

The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active class participation is required.

Content
This course on user innovation extends courses on knowledge management and innovation as well as marketing. The students are introduced to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through their cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies. Theoretical underpinnings taught in the course include models of innovation, the structuration of technology, and an introduction to entrepreneurship.

Lecture notes
The slides of the lectures are made available and updated continuously through the SMI website:
This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

The reader and additional lecture material and exercises will be posted on Moodle.

Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

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

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

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

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

Does not take place this semester.

The lecture treats the social intercourse with risks of technical systems. The notion of risk and the perception of risk are discussed by case studies (e.g. nanotechnology) and socio-political instruments for decision-making are presented. Methods are presented that can be applied to deal with environmental risks and how they can be used for sustainable innovation.

### Literature

Relevant literature for the exam includes the slides and the reading assignments. The corresponding papers are either available from the author online or distributed during class.

Reading assignments: please consult the SMI website:

### 701-0747-00L Environmental Policy of Switzerland

**W** 3 credits 2G E. Lieberherr

**Abstract**

This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

**Objective**

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

**Content**

The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

**Lecture notes / Literature**

The reader and additional lecture material and exercises will be posted on Moodle.

**Prerequisites / notice**

The detailed semester program (syllabus) is made available to the students at the beginning of the semester. During the lecture we will work with Moodle and eduApp. We ask that all students register themselves on these platforms before the lecture and to bring a laptop, tablet or smartphone to class, so that you can complete exercises using Moodle and eduApp.

**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Sensitivity to Diversity | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |
| | Self-direction and Self-management | assessed |

### 351-1158-00L Principles of Economics

**W** 3 credits 2G U. Renold, T. Bolli, P. McDonald, M. E. Oswald-Egg, F. Pusterla

**Abstract**

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

**Objective**

After successful completion of the course you will be able to:

- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

**Content**

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

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

Market failure: What happens when prices give wrong signals?

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

National accounts: How big is the Swiss economy?

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

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

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

**Lecture notes / Literature**


Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Decision-making | assessed |
| Problem-solving | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |
| Self-direction and Self-management | assessed |

### 701-0985-00L Social Intercourse with Current Environmental Risks

**W** 1 credit 1V B. Nowack

**Does not take place this semester.**

The lecture treats the social intercourse with risks of technical systems. The notion of risk and the perception of risk are discussed by case studies (e.g. nanotechnology) and socio-political instruments for decision-making are presented. Methods are presented that can be applied to deal with environmental risks and how they can be used for sustainable innovation.
Objective
- Getting acquainted with the extended risk concept
- Evaluation of the risks caused by technology within the societal context
- Knowledge about how science and society handle current environmental risks (examples: gene- and nanotechnology)
- Knowledge about handling risks (e.g., precautionary principle, protection goal, damage definition, ethics)
- Knowledge about possibilities for sustainable innovation

Content
- Risks and technical systems (risk categories, risk perception, risk management)
- Illustration with case studies (nanotechnology)
- Risk perception (politics, science, media, etc.)
- Decision making (technology assessment, cost-benefit analysis, etc.)
- The role of the media
- Prospects for future developments

Lecture notes
Copies of slides and selected documents will be distributed

Prerequisites / notice
The lecture is held biweekly (for 2 hours). The dates are 3.9.; 30.9. (instead of 7.10); 21.10.; 4.11.; 18.11.; 2.12.; 16.12.

363-1109-00L Introduction to Microeconomics  W  3 credits  2G  M. Wörter, M. Beck

GESt (Science in Perspective): This course is only for students enrolled in a Bachelor's degree programme.

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

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

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

Objective
Students acquire a deeper understanding of basic microeconomic models.

Content
Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

Lecture notes
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Literature

Prerequisites / notice
This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

363-1044-00L Applied Negotiation Seminar  W  3 credits  2S  A. Knobel

Number of participants limited to 30.

Prerequisites: Successful completion of lectures "363-1039-00L Introduction to Negotiation".

Abstract
The block-seminar combines lectures introducing negotiation and negotiation engineering with the respective application through in-class negotiation case studies and games.

Objective
In this seminar students can expect to:
- Learn more theory of negotiation and apply this learning in simulated negotiations
- Have their perceptions of rationality, fairness and trust challenged through little embedded experiments
- Learn to recognize and analyze negotiation contexts and interests and generate creative solutions
- Learn to negotiate under pressure (with time and mandate restrictions) and experience (and potentially chair) a formal negotiation
- Learn to read, analyze and present a scholarly paper
Content

This block seminar is an extension of the course “Introduction to Negotiation” and provides more detailed insight into key aspects of the field of negotiation and negotiation engineering.

In particular,

- a series of brief lectures will outline foundational aspects of negotiation science, such as rationality, fairness, and trust, as well as the possible application of machine learning in negotiation
- three practitioners will describe lessons learnt in their negotiation domains (diplomacy, labor, and business) and allow time for Q&A and discussion
- Professor Ambühl will elucidate further current cases from his professional experience
- students will apply course input in a number of challenging simulations (ranging from simple 30 minute games to full-fledged international ten party negotiations). In each game they will be asked to represent a party and negotiate as skillfully as they possibly can within the constraints of their mandate
- each student will be assigned a scholarly paper (20 to 30 pages) between the two blocks to read. They will give a 20 minute group presentation with one or two of their peers and submit a brief reflection report after the seminar

The course size is deliberately limited (30 maximum) to enable ample opportunity to interact with the lecturers, guests and each other.

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363-1050-01L Simulation of Negotiations (Exercises) W 1 credit 1U M. Ambühl, A. Knobel

Abstract

The Global Studies Institute (University of Geneva) is organizing a simulation seminar on the conflict in Nagorno-Karabakh in collaboration with MGIMO Moscow (TBC) and the Chair of Negotiation and Conflict Management (ETHZ).

Objective

The two main aims of the exercises are: 1) to become familiar with the historical, economic, political dimensions of the conflict in Nagorno-Karabakh (first session); 2) to work on the mandates for the simulation under supervision of the lecturers (second session).

Content

For the first session students will be asked to prepare and deliver a 15 minute talk on some aspect of the conflict.

Dates, Time:
First session: 12 October 2021, 13-17 h
Second session: 9 November 2021, 8-12 h

Prerequisites / notice

In order to participate in this module students also need to apply and register for the lecture 363-1050-00 L Simulation of Negotiations.

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851-0180-00L Research Ethics W 2 credits 2G G. Achermann, P. Emch

Number of participants limited to 40

Abstract

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective

Participants of the course Research Ethics will

- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;
I. Introduction to Moral Reasoning
1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!)
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Decision-making | assessed |
| Domain D - Personal Competencies | Problem-solving | assessed |
| | Communication | assessed |
| | Cooperation and Teamwork | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |

Environmental Ethics
W 2 credits 2V A. Deplazes Zemp

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Content
- Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarization with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

Lecture notes
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.
This course will review some critical reflections on scientific epistemology, challenging prevalent notions of scientific objectivity. We will

Philosophy of Physics
M. Hampe

The seminar will discuss problems of the unity of physics, emerging laws, and the role of human beings in the age of anthropocene.

Günther Anders: The Antiquity of Man
W 3 credits 2S M. Hagner

Abstract
Participants should develop a clear view of the epistemological foundations of their work and its consequences for philosophy of science and philosophy of nature.

Content
Newton's opus magnum of 1687 is still called a philosophy of nature: "Philosophiae Naturalis Principia Mathematica". The separation of physics from philosophy is new, and institutionally executed only in the 19th century. Since the book is more relevant than ever: What is the role of human beings in the Anthropocene?

Philosophy of Physics
W 3 credits 3S M. Hampe, R. Wallny

Abstract
Close reading of and reflection about selected texts from physicists (e.g. C.F. Weizsäcker, Wilczek, Susskind) on the philosophical problems and consequences of their work.

Objectives
Students learn about the different types of arguments and conceptions in philosophical texts and their historical context. They should learn to understand the descriptive and critical value of texts in regard to the topic of war.

Knowledge and Practice in Philosophy of War
W 3 credits 2S

Abstract
In the seminar we read classical texts from the field of "philosophy of war". Due to today's technological advancements and ecological problems, we will also discuss contemporary conceptions of war such as lethal autonomous weapons and climate change. Important questions that arise are: Is the concept of war only applicable to human society? Is there a difference between politics and nature?

Objective
The course aims are:
1. To introduce students to the historicity of mathematics
2. To develop critical reflection concerning the nature of mathematical objects
3. To open the students' horizons to the plurality of mathematical cultures and practices

A Sampler of Histories and Philosophies of Mathematics
W 3 credits 2V R. Wagner

Abstract
This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objectives
The course will review some critical reflections on scientific epistemology, challenging prevalent notions of scientific objectivity. We will start with German critiques from the first half of the 20th century (Heidegger, Husserl, Frankfurt school), go on to French critiques from the second half (Foucault, Latour), and conclude with recent feminist and post-colonial critiques.

Critiques of Scientific Objectivity
W 3 credits 2S R. Wagner

Abstract
This course analyses the evolution of the relation between science and philosophy during the Middle Ages and the Early Modern Period.
The course is focused on the investigation of scientific thought between 1000 and 1700, that is to say the period that saw the flourishing of natural philosophy and the birth of the modern scientific method. Several case-studies, taken from different scientific fields (especially algebra, astronomy, and physics) are presented in class in order to examine the relation between science and philosophy and the shift from medieval times to the early modern world.

**052-0517-21L** Theory and Practice: Heterotopia, Referential Space and Spatial Effects  
**Objective** The students gain insight into the spectrum of epistemological and perceptual theories, learn to read them and analyze and critique their respective requirements. From this work an object relationship model is developing in progress, which serves self-examination in the design process as well as the evaluation of architectural situations in general and in particular. The writing of "scientific diaries" in which the contents of the colloquium are combined with the everyday experience of the students in free form, trains the concentrated result-oriented thinking in general, as well as in architectural situations.

**Content** In 1967, Foucault showed certain entanglements of space with his concept of heterotopia; a little later, Pierre Bourdieu established a multidimensional space sociologically with his concept of field. The seminar also discusses such interweaving in current local situations and tries to think about potentials for spatial policy practice.

**Prerequisites / notice** Cooperation in the form of discussions and scientific diary.

The additional personal work (besides the course) is about 20 working hours for the creation of a scientific journal, individual deepening and filming!

**851-0081-00L** Artificial Intelligence. Interdisciplinary Perspectives  
**Abstract** In the last 50 years, research on artificial intelligence (AI) has repeatedly boomed but failed to deliver on its great promises. In the last decade, however, especially the deep learning approach has achieved remarkable results. This eLearning-seminar will discuss epistemological, but also ethical and political aspects of these recent developments in interdisciplinary perspective.

**Objective** Students will learn to reflect on one of the most attention-grabbing technologies of recent years in terms of its epistemological basis and social impact.

**Content** In the last 50 years, research on artificial intelligence (AI) has repeatedly boomed but failed to deliver on its great promises. In the last decade, however, especially the deep learning approach has achieved remarkable results and is already applied in many contexts. Since this approach breaks with assumptions of the older symbolic approaches of AI research, a new philosophical discussion is needed. Therefore, the interdisciplinary seminar will start from the classical philosophical debate, which was shaped by thinkers like Herbert Dreyfus and John Searle and focused on the concept of the rule following, in order to confront it with the newer state of research, its data driven approach and the concept of learning. We will discuss the consequences and challenges of these new approaches in AI for their theoretical and philosophical reflection. In a second step, the seminar will discuss not only epistemological, but also ethical and political aspects of the recent developments in AI in interdisciplinary perspectives.

**Prerequisites / notice** The seminar will be conducted as an eLearning event in cooperation with LMU Munich.

**851-0079-00L** Ignorance and Error in the Sciences  
**Abstract** Ignorance and error are usually unwelcome participants in the sciences and scientific practices, but we know that we cannot get rid of them. In this seminar we will analyze and discuss the different roles of ignorance and error in sciences from a philosophical perspective.

**Objective** – Students apply philosophical conceptions of ignorance and error to sciences and their own studies.

**Content** Ignorance and error are usually unwelcome participants in the sciences and scientific practices, but we know that we cannot get rid of them. In this seminar we will analyze and discuss the different roles of ignorance and error in sciences from a philosophical perspective.

**851-0096-00L** Science in Society  
**Abstract** Whose voice should count how much? On the authority of the sciences in democracy.

**Objective** Not a few members of the elites argue that important issues in democracy like policies against climate change, free trade agreements, urban planning are too complicate for the people. Experts should have a stronger say in politics. Less democracy = more rationality? The course should give an answer to this question.

**851-0198-00L** Philosophy of Psychiatry  
**Abstract** Psychiatry is one of the most controversial areas of medicine because it is concerned with beliefs, moods, relationships, and behaviors. This course offers an overview of some representative topics in philosophy of psychiatry.

**Objective** The objective of this course is to offer historical context and philosophical reflection on mental disorders and psychiatric practices.

**Content** Psychiatry is one of the most controversial areas of medicine. All medicine involves some negotiation about assumptions and values, at the professional-patient and societal levels. For example, its clinical categories are imposed on the subject, who is interpreted according to a given physiological (but also political and economical) framework. However, because psychiatry is primarily concerned with beliefs, moods, relationships, and behaviors, this negotiation actually constitutes the bulk of its clinical endeavors. This course offers an overview of some representative topics in philosophy of psychiatry. Some of these are the character of mental disorders, the takeover of the mind by the medical model, the demarcation of normal and abnormal behavior, the influence of culture in the understanding of mental disorders, a critical understanding of the DSM and its evolution, and the interplay between psychiatry and legal responsibility.

**851-0351-00L** Philosophy of Religion: Faith and Knowledge According to Kant (University of Zurich)  
**Abstract** Mind the enrolment deadlines at UZH: 
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

**Objective** Does (religious) faith stand in opposition to knowledge (as, e.g., represented by modern natural sciences)? Are faith and knowledge located in totally different logical spaces (so that conflict and dialog between them would be meaningless from the outset)? Or are there more nuanced accounts of the relation of (religious) faith, (religious and non-religious) belief and knowledge? And what would such accounts entail for the relation of religion and science? The seminar will discuss these questions and other critical interpretation of philosophical texts (mainly) from Immanuel Kant’s philosophical oeuvre.

**851-0352-00L** Introductory Course in Philosophy of Religion  
**Abstract** No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. 
UZH Module Code: 23L8002

**Objective** Does (religious) faith stand in opposition to knowledge (as, e.g., represented by modern natural sciences)? Are faith and knowledge located in totally different logical spaces (so that conflict and dialog between them would be meaningless from the outset)? Or are there more nuanced accounts of the relation of (religious) faith, (religious and non-religious) belief and knowledge? And what would such accounts entail for the relation of religion and science? The seminar will discuss these questions and other critical interpretation of philosophical texts (mainly) from Immanuel Kant’s philosophical oeuvre.

Abstract
The course offers an introduction to analytical, phenomenological and hermeneutic philosophy of religion. Influential positions, vital questions and significant developments will be discussed and critically reflected.

Objective
Special emphasis will be placed on the relationship between religious and scientific discourse in the 20th century. To get a better grasp of the complexity of this relationship, different narratives will be examined as to how the modern ideal of modelling all cognitive values on scientific ones came to exert supreme authority in Western societies. The still prevalent, mainstream view has deep roots in 19th century positivism, which assumed a necessary historical progress from religion to metaphysics to science. In this perspective, scientific knowledge uncovers “objective” reality by displacing superstition and more “primitive”, mythical or metaphysical accounts of human and cosmic origins. On the other hand, there is the more recent, “heterodox” view advanced by philosophers and historians of science like S. Gaukroger, that the success of science in the West in the early-modern era might be related to its close association with theology rather than attempts to emancipate itself from it. The question here arises: What traditional ideas of God and religious faith contributed to the modern ideal of knowledge and truth – an ideal which, in a strange twist of historical irony, finally led to the seeming exclusion of all religious discourse from the properly scientific quest for real knowledge and truth in present-day secular societies?

Political Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tr>
<td>851-0589-00L</td>
<td>Technology and Innovation for Development</td>
<td>W Dr</td>
<td>3 credits</td>
<td>2V</td>
<td>P. Aerni</td>
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Abstract
Technological change plays a crucial role in efforts to create a more sustainable future. In this context, policy decision makers must design rules that minimize its risks and maximize its benefits for society at large. The course discusses this challenge from an interdisciplinary perspective taking into account legal, economic, historical, development and environmental aspects.

Objective
- to recognize the challenges and opportunities of technological change in terms of sustainable development
- to become familiar with policy instruments to promote innovation
- to improve understanding of political decision-making processes in the regulation of science & technology
- improved understanding of the role of science and technology in the context of human and societal development

Content
Science and Technology Policy is normally associated with the improvement of national competitiveness; yet, it is also an integral part of effective environmental and development policies. The course will discuss the challenges and opportunities of technological change in terms of sustainable development and show how public policy on the national and the international level is responding to this change.

In this context, students are to become familiar with the basic principles of political economy and New Growth Theory and how such theories help explain political decisions as well as political outcomes in the area of Science, Technology and Innovation. State interventions are either designed to regulate (e.g. environmental regulations, anti-trust law) or facilitate (e.g. intellectual property rights protection, public investment in R&D and technical education, technology transfer) technological change. This will be illustrated by looking at different industries and different national systems of innovation. Subsequently the positive and negative consequences for society and the natural environment will be discussed from a short-term and a long-term perspective.

Lecture notes
Reader with issue-specific articles. E-version is partly available under https://www.ethz.ch/content/specialinterest/gess/cis/international-relations/en/teaching/materials/tech.html
Swiss Foreign Policy
World Politics Since 1945: The History of International Relations (Without Exercises)

Prerequisites / notice
The 2-hour course (5-7 p.m.) will be held as a series of lectures. The course materials will be available in form of an electronic Reader at the beginning of the semester.
The class will be taught in English.
Students will be asked to make a contribution in class choosing one out of three options:
(a) presentation in class (15 Minutes) based on a paper to be discussed on a particular day in class
(b) review paper based on a selected publication in the course material
(c) preparation of questions for a selected invited speaker, and subsequent submission of protocol about the content of the talk and the discussion
In addition, they will have to pass a written test at the end of the course in order to obtain 3 credit points in the ECTS System. In the final mark (a) will have a weight of 40% and (b) 60%.

853-0038-00L
Swiss Foreign Policy

W 3 credits 2V D. Möckli

Abstract
This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since the early 20th century, we will discuss the determining factors of Swiss foreign policy and examine, together with guest speakers from the foreign ministry, current international developments and respective foreign policy challenges. Students should acquire a sound understanding of Swiss foreign policy and the relevant academic and political debates associated with it.

Objective

Content

Lecture notes
Literature
Prerequisites / notice

Students will receive a handout of slides accompanying the lectures.
The required reading will be listed at the beginning of the semester.
The course will be supported by an e-learning environment.

853-0047-01L
World Politics Since 1945: The History of International Relations (Without Exercises)

W 3 credits 2V L. Horovitz

Abstract
This lecture series provides students with an overview of the development of international relations since the end of World War II. The first part of the series deals with the development of world order and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

Objective
By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of the Second World War.

Content
cf. "Diploma Supplement"

Prerequisites / notice
The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver roos (oliver.roos@sipo.gess.ethz.ch).

Conflict Research I: Political Violence

853-0015-01L

W 3 credits 2V A. Juon

Abstract
Introduction to research on political violence in domestic and international politics. This course covers the causes and solutions to different types of political violence including interstate wars, civil wars, terrorism or social protests.

Objective
Knowledge on different types of political violence and their causes.

Content
This course offers an introduction to research on the causes and solutions to political violence in domestic and international politics. First, we discuss the definitions and concepts used in conflict research, the data and methods commonly applied and their historical development. Second, we focus on interstate wars and examine in this context state formation, nationalism and democracy. The third part of the course focuses on different types of political violence, including civil war, terrorism or social protests.

Prerequisites / notice
The course «Conflict Research II» in the following semester further examines civil wars.

European Integration (Seminar without Tutorial)

853-0302-01L

W 2 credits 2S R. Sczepanski

Abstract
The lecture course covers the theory, development, and core policy fields of European integration as well as structures and processes of the EU as a decision- and policy-making system.

Objective
The seminar is designed to help students understand the European Union as a particular kind of political system that differs both from the nation-state and from other international organizations. It imparts basic knowledge on the development, institutions, procedures, and policies of the EU and provides an introduction to major approaches to integration theory and political science research on the EU.

Content
1. Introduction
2. Theories of European integration
3. Institutional development of European integration
4. Development of political integration
5. Internal market and monetary union
6. Internal and external security policies
7. Constitutionalization
8. Widening and differentiation
9. European integration in crisis
10. Institutions
11. Law-making and law enforcement
12. Statehood and democracy
13. Switzerland, the EEA and Neighbourhood Policies

Lecture notes
The seminar covers the theory, development, and core policy fields of European integration as well as structures and processes of the EU as a decision- and policy-making system.

Literature
Die Literatur wird auf Moodle bereitgestellt.

Prerequisites / notice
The grade is based on a written exam.

International Environmental Politics

860-0023-00L

W 3 credits 2V T. Bernauer

Particularly suitable for students of D-ITET, D-USYS

Abstract
This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

Objective
The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.
This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Assigned reading materials and slides will be available via Moodle.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

### 853-0061-00L Introduction to Cybersecurity Politics

**W 3 credits 2G** M. Dunn Cavelti, F. J. Egloff

**Abstract**

The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures).

**Objective**

Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.

**Content**

We start with an overview of cybersecurity issue from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulatory contexts).

**Lecture notes**

A script with background information and comments on the literature will be made available at the beginning of the semester.

**Literature**

A literature for each session will be available on Moodle.

**Prerequisites / notice**

The lecture is being supported by a website on Moodle.

### 853-8002-00L The Role of Technology in National and International Security Policy

**W 3 credits 2G** M. Haas, A. Dossi, M. Leese, O. Thränert

**Abstract**

The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

**Objective**

Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.
Is Yemen a failed state? The Yemen Republic is the result of the unification in 1990 of two former states: The Yemen Arab Republic

1. Examine the concept of failed state within the International relations literature.
2. Take a closer look at Yemen(s) political history(ies), its/their political and social structures, and power dynamics.

Students with a strong background in machine learning and excellent programming skills (preferably in Python)

Note: The course AI4Good is not related to Hack4Good, which is a students' initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/

In this course students deepen their knowledge about global development and sustainability issues. We will show five movies each of them linked to one of the five P`s (Planet, People, Prosperity, Peace and Partnerships) reflecting the topics of the 2030 Agenda. Afterwards the movie will be critically discussed with researchers and relevant stakeholders from the broader society.

Students are expected to write a paper and take a closer look at Yemen(s) political history(ies) and its/their political and social structures. Students are expected to write a paper and make a presentation.

This seminar looks at the concept of failed states and how useful it can be in describing the situation in a country like Yemen. It will also focus on the misuse potential.

Research and technologies emerging from the life sciences bring beneficial aspects to our society but also unforeseeable risks regarding biosafety and biosecurity. In this course, students will learn about the advances in science and technology and their implications for society and international treaties (BWC or CWC) and their social, ethical and legal responsibilities as life scientists.

By the end of this course, students will be able to critically assess their own research on the ability to present scientific results or methods with believable or malevolent intentions (dual-use) and will be able to integrate strategies into their research design to reduce the misuse potential.
Content

Life sciences evolve rapidly supported by developments in related disciplines. However, while those new and emerging technologies greatly benefit society, they additionally bring along predictable as well as unforeseeable risks in the context of biosafety and biosecurity.

The ability of life science professionals to critically assess their own research regarding potential misuse risks and how to reduce these is a crucial aspect to maintain research integrity against the background of novel security concerns arising from the speed and dynamics of advancements in the life- and associated sciences.

During the course, you will discuss about your societal, ethical, and legal responsibilities as life scientists. You will become aware of biosecurity and biosafety risks and what scientists can do to minimize misuse potential in highest-risk research ("dual use research of concern"). A strong focus of the seminar lies on interactive group work for which you will be able to build on your individual experiences and scientific background. Additionally, a combination of lectures and input from guest speakers will provide you with essential background information and insights into real-world applications. You will understand the dual-use dilemma and learn about biological warfare, biological terrorism, and the international prohibition regimes; the national implementation of the biological and toxins weapons convention and about efforts to build the web of prevention against the misuse of life sciences.

Psychology, Pedagogics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
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<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs “Teaching Diploma” or “Teaching Certificate”. It is about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung; Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<tr>
<td>Lecture notes</td>
<td>Foli en werden zur Verfügung gestellt.</td>
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</table>

851-0238-01L | Support and Diagnosis of Knowledge Acquisition Processes (EW3) | W | 3 | 3S | P. Edelsbrunner, J. Maue, C. M. Thurn |
| Prerequisites / notice | This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence. |
| Abstract | In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school. |
| Objective | The main goals are: (1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition. (2) You have a basic understanding about psychological test theory and can appropriately administer tests. (3) You know various techniques of formative assessment and can apply these to uncover students' misconceptions. |

851-0252-01L | Human-Computer Interaction: Cognition and Usability | W | 3 | 2S | H. Zhao, S. Credé, C. Hölscher |
| Number of participants limited to 35. | Particularly suitable for students of D-ARCH, D-INFK, D-ITET |
| Abstract | This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects. |
| Objective | This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course). |

851-0252-12L | The Science of Learning From Failure | W | 2 | 2S | M. Kapur, E. Ziegler |
| Number of participants limited to 60. | |
| Abstract | We can learn from failure. But, what does “failure” mean? And, what, how, and why do we learn from failure? This course covers research from the cognitive, educational, and learning sciences that addresses the role of failure in human learning. Students will critically examine how failure affects thinking, knowledge, creativity, problem-solving, and motivation. |
Students will:
- Critically read and analyze articles on research that addresses failure in learning
- Participate in in-class problem-solving activities around research in failure
- Discuss and reflect upon topics in both online and face-to-face formats
- Engage in activities through the online platform
- Complete a final paper on a subtopic related to failure in learning

By the end of the course, students should be able to:
- Demonstrate a critical understanding of the role that failure plays in learning
- Discuss how and why failure can benefit learning
- Discuss how and why failure does not facilitate learning
- Apply understanding to a related sub-topic

We learn from our mistakes, or rather, we hope that we do. Another way to say this is that we can learn from failure. But, what does “failure” mean? What, how, and why do we learn from failure? This course covers research from the cognitive, educational, and learning sciences that addresses the role of failure in human learning. Students will critically examine how failure affects development of knowledge, creativity, problem-solving, and general thinking and learning. More specifically, they will have the opportunity to question and evaluate the potential relationships between the facets around failure within individual, inter- nal, cultural, societal, and global contexts through seminal readings and problem-solving activities. Students from any discipline are welcome to this course to learn more about how failure can be harnessed to improve our knowledge, capabilities, innovations, teamwork, and contribute to the larger global world.

This seminar is an interactive course, thus attendance and classroom participation are required. Processing of online tasks is a requirement for obtaining credit points.

The course is held as 2 separate courses with each a maximum of 30 students: one course in German and one course in English.

### 363-0311-00L

#### Psychological Aspects of Risk Management and Technology

**W 3 credits 2V**

**G. Grote, N. Bienefeld-Seall, J. Schmutz, R. Schneider, M. Zumbühl**

**Number of participants limited to 65.**

#### Abstract

Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are treated. Three components of risk management (risk identification/evaluation, risk mitigation, risk communication) and underlying psychological and organizational processes are discussed.

#### Objective

- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about and (partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

#### Content

The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication
- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty
- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)
- Group projects related to company case studies

**701-0721-00L**

#### Psychology

**W 3 credits 2V**

**R. Hansmann, A. Bearth, M. Siegrist**

This course provides an introduction to psychological research and modelling, focusing on cognitive psychology and the psychological experiment. Participants learn to formulate problems for psychological investigation and apply basic forms of psychological experiment.

#### Objective

Students are able to
- describe the areas, concepts, theories, methods and findings of psychology.
- differentiate scientific psychology from “everyday” psychology.
- structure the conclusions and significance of an experiment. according to a theory of psychology.
- formulate a problem for psychological investigation.
- apply basic forms of psychological experiment.

#### Content

Einführung in die psychologische Forschung und Modellbildung unter besonderer Berücksichtigung der kognitiven Psychologie und des psychologischen Experiments. Themen sind u.a.: Wahrnehmung; Lernen und Entwicklung; Denken und Problemlösen; Kognitive Sozialpsychologie; Risiko und Entscheidung.

**851-0252-08L**

#### Evidence-Based Design: Methods and Tools For Evaluating Architectural Design

**W 3 credits 2S**

**M. Gath Morad, C. Hölscher, L. Narvaez Zurtuche, C. Veddeler**

This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered. Students who have attended or will attend the lecture "Introduction to Law for Civil Engineering and Architecture" (851-0703-03L) or "Introduction to Law" (851-0708-00L), cannot register for this course unit.

particularly suitable for students of D-ARCH, D-MAVT, D-MATL.

Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

Objective The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architecture and design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

**Law**

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0735-09L</td>
<td>Workshop &amp; Lecture Series on the Law &amp; Economics of Innovation</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>S. Bechtold, H. Gersbach</td>
</tr>
</tbody>
</table>

This series is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary research on intellectual property, innovation, antitrust, privacy & technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. & beyond.

Objective After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas.

Content The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented.

Lecture notes Papers discussed in the workshop and lecture series are posted in advance on the course web page.

Suzanne Scotchmier, Innovation and Incentives, 2004
Bronwyn Hall / Nathan Rosenberg (eds.), Handbook of the Economics of Innovation, 2 volumes, Amsterdam 2010
Bronwyn Hall / Dietmar Harhoff, Recent Research on the Economics of Patents, 2011

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Taught</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>Taught</td>
<td>Assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>Taught</td>
<td>Assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>Taught</td>
<td>Assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>Taught</td>
<td>Assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>Taught</td>
<td>Assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>Taught</td>
<td>Assessed</td>
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851-0703-00L

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0708-00L</td>
<td>Introduction to Law</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>O. Streiff Gnöpff</td>
</tr>
</tbody>
</table>

Students who have attended or will attend the lecture "Introduction to Law for Civil Engineering and Architecture" (851-0703-03L) or "Introduction to Law" (851-0708-00L), cannot register for this course unit.

This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.

Objective Students are able to identify basic structures of the legal system. They understand selected topics of public and private law and are able to apply the fundamentals in more advanced law classes.

Content Basic concepts of law, sources of law.
Private law: Contract law (particularly contract for work and services), tort law, property law.
Public law: Human rights, administrative law, procurement law, procedural law.
Insights into the law of the EU and into criminal law.
Documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15143).

See Literature.

Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CVidfG70zQ0). However, this course prioritizes applications of contract design. Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolled in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Prerequisites / notice
Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalbertocalderaherrera@uzh.ch).

Lecture notes
Handouts, prerecorded videos, slides, and other materials

Number of participants limited to 45

Law and Urban Space

Particularly suitable for students of D-ARCH

Legal rules are tied to urban space. Illustrative is the relation between land ownership and urban morphology or between zoning and the functional dimension of urban space. Legal concepts (from property law, fundamental rights and administrative law) with spatial impacts are introduced and related to the theory of urban design. Moreover, it is discussed how these concepts shape specific places.

Objective
Students recognize the interplay between legal structures and urban space. They can describe legal concepts with spatial impact.

Content
Using the the term «lawscape» (Philippopoulos-Mihalopoulos), we initially discuss general aspects of the interplay between legal rules and urban space.

The first part of the course is about the morphological dimension of urban space. We compare positions of urban planners like Trancik (Finding Lost Space) or Rowe/Koetter (Collage City) with property law. Freedom of property in turn contrasts to the theoretical approaches of Bernoulli (Die Stadt und ihr Boden) or Rossi (L’architettura della città). Using court decisions concerning nail houses, we study the tensions between urban development and the system of property ownership.

The second part of the course is about the functional dimension of urban space. Key concept is the zone (cf. CIAM 4). This concept is criticized (Wolfrum, Zoning Bien Défini). We compare the concept as well as the critique with the main concerns in spatial planning law. Environmental law and neighbouring rights are also relevant.

In the third part of the course, we work on the social, visual and temporal dimensions of urban space. The positions of Jacobs (The Death and Life of Great American Cities), Cullen (Townscape) or Lynch (The Presence of the Past) are compared with the dichotomy public space/private space, safety regulations, regulations on design reviews or heritage protection laws.

Working tools are theoretical texts, legal rules, court decisions as well as site analyses. Students undertake a case study in small groups. Selected case studies are presented and discussed in a final meeting.

See Literature.

Documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15143).
The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities.

Objective

Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

Content


Prerequisites / notice

Es wird mit Folien gearbeitet, die als PDF über die elektronische Dokumentenablage (ILIAS) auf dem System der ETHZ vorgängig abrufbar sind. Auf dem Termin- und Themenplan (ebenfalls online abrufbar) sind Links zu Gesetzestexten und weiteren Unterlagen abrufbar.

Lecture notes

Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999
Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 6.A., Bern 2016

851-0709-00L E-Business-Law W 2 credits 2V H. Peter

Abstract

The course deals with the Swiss Code of Obligations (contracts, torts) and on Property Law (ownership, mortgage and easements). In addition, the course will provide a short overview of Civil Procedure and Enforcement.

Objective

Teaching of the principles of law, particularly private law. Introduction to law.

Content

Le cours de droit civil porte notamment sur le droit des obligations (droit des contrats et responsabilité civile) et sur les droits réels (propriété, gages et servitudes). De plus, il est donné un bref aperçu du droit de la procédure et de l'exécution forcée.

Literature

Für diebstoffliche récentes des lois fédérales, en langue française (Code civil et Code des obligations) ou italienne (Codice civile e Codice delle obbligazioni), disponibles auprès de la plupart des librairies.

Sont indispensables:
- le Code civil et le Code des obligations;
- la procédure forcée.
Sont conseillés:
- Nef, Urs Ch.: Le droit des obligations à l'usage des ingénieurs et des architectes, trad. Bovay, J., éd. Payot, Lausanne

Remarques

- Les cours de droit civil et le droit de droit public (2e sem.) sont l'équivalent des cours "Recht I" et "Recht II" en langue allemande et des exerces y relatifs.
- Les examens peuvent se faire en français ou en italien.
- Examen au 1er propédeutique; convient pour travail de semestre.
- Con riassunti in italiano. E possibile sostener le l'esame in italiano.

851-0727-02L Business Law W 2 credits 2V D. Rosenthal

Abstract

The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaking information technology activities.

Objective

The objective is knowing and understanding key legal concepts relevant for doing e-business, in particular understanding how e-business is regulated by law nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications.

Content

Vorgesehene Strukturierung der Vorlesung:

1) Welches Recht gilt im E-Business?
   - Internationalität des Internets
   - Reguläre Branchen

2) Gestaltung und Vermarktung von E-Business-Angeboten
   - Verwendung fremder und Schutz der eigenen Inhalte
   - Haftung im E-Business (und wie sie beschränkt werden kann)
   - Domain-Namen

3) Beziehung zu E-Business-Kunden
   - Verträge im E-Business, Konsumentenschutz
   - Elektronische Signaturen
   - Datenschutz
   - Spam

4) Verträge mit E-Business- Providern
   Änderungen, Umstellungen und Kürzungen bleiben vorbehalten. Der aktuelle Termin- und Themenplan ist zu gegebener Zeit über die elektronische Dokumentenablage abrufbar.

Lecture notes

Es wird mit Folien gearbeitet, die als PDF über die elektronische Dokumentenablage (ILIAS) auf dem System der ETHZ vorgängig abrufbar sind. Auf dem Termin- und Themenplan (ebenfalls online abrufbar) sind Links zu Gesetzestexten und weiteren Unterlagen abrufbar. Schliesslich wird jede Vorlesung auch als Podcast aufgezeichnet, der jedoch nur für die Studierenden mit einem Passwort (erhältlich beim Dozenten) zugänglich sind.

Literature

Weiterführende Materialien, Links und Literatur sind auf dem Termin- und Themenplan aufgeführt (zu gegebener Zeit abrufbar über die elektronische Dokumentenablage).

Prerequisites / notice

Die Semesterendprüfung war vor Corona in Form eines schriftlichen Kurztests (normalerweise ein MC, im letzten Jahr Coronaabedingt aber eine Falllösung) in der letzten Doppelstunde ausgestaltet. Es wird angegeben, welche Unterlagen beim jeweiligen Thema den Prüfungsstoff definieren. Der Test wird möglicherweise elektronisch durchgeführt.

851-0735-10L Business Law W 2 credits 2V P. Peyrot

Abstract

Particularly suitable for students of D-ITET, D-MAVT

Number of participants limited to 100
The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.

**Objective**
The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall be familiar with the issues of corporate compliance, i.e. the systems to ascertain that all legal and ethical rules are observed.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**
A comprehensive script will be made available online on the moodle platform.

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**851-0738-00L Intellectual Property: Introduction**

- **W 2 credits 2V**
- **M. Schweizer**
- Particularly suitable for students of D-CHAB, D-INF, D-ITET, D-MAVT

**Abstract**
The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

**Objective**
The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

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**851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector**

- **W 2 credits 2V**
- **K. Houshang Pour Islam**
- Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT

**Abstract**
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

**Objective**
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

**Prerequisites / notice**
The lecture addresses students in the fields of engineering, science and other related technical fields.

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**851-0760-00L Building a Robot Judge: Data Science for Decision-Making (Course Project)**

- **W 3 credits 2V**
- **E. Ash**
- Particularly suitable for students of D-INF, D-ITET, D-MTEC

**Abstract**
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

**Objective**
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

**Content**
Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

**851-0761-00L Building a Robot Judge: Data Science for Decision-Making (Course Project)**

- **W 2 credits 2V**
- **E. Ash**

This is the optional course project for "Building a Robot Judge: Data Science for the Law."

Please register only if attending the lecture course or with consent of the instructor.

Some programming experience in Python is required, and some experience with text mining is highly recommended.

**Abstract**
Students investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. This is the extra credit for a larger course project for the course.
This course has four main goals:

A. Algorithms and Fairness
   - Any students enrolling in the course must complete a short writing assignment within two weeks of registering. Please contact the instructors via email (aileen.nielsen@gess.ethz.ch) for information about the assignment and for access to the course slack workspace.
   - From a legal, social science, and applied mathematics perspective, we address the increasingly important question of what AI fairness means and how AI fairness can be addressed by legal, social science, and applied mathematical research to inform policy making.
   - Explain why fairness and AI is a highly contested and unresolved problem in law.

B. Contract Design II
   - This course is taught by Professor Alexander Stremitzer (https://lawecon.ethz.ch/group/professors/stremitzer.html).
   - To be considered for Contract Design II, you must have completed Contract Design I in the same semester.
   - Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.
   - Students enrolling in the course must complete a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract.
   - There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the content and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegalberto.calderaherrera@uzh.ch).

C. Project in Behavioural Finance
   - In this seminar, students will study cognitive processes, behaviour and the underlying biological response to financial decisions. Research methods such as asset market experiments, lottery games, risk preference assessment, psychometrics, neuroimaging and psychophysiology of decision processes will be discussed. Financial bubbles and crashes will be the core interest.
   - This course has four main goals:
     1) To learn about the most important topics within Behavioural Finance
     2) To learn how to conduct behavioural studies, design experiments, plan data collection and experimental tasks
     3) To learn about causes of market crashes, factors that influence them, traders' behaviour before, during and after financial crises
     4) To investigate a topic of interest, related to behaviour of traders during market crashes.

D. Network Modeling
   - Particularly suitable for students of D-INFK and in the MSc Data Science
   - Students are required to have basic knowledge in inferential statistics, such as regression models.
Network Science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks. Statistical and numerical methods have been developed to fit these models to empirical data. Emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources. Students will be able to develop hypotheses that relate to the structures and dynamics of (social) networks, and tests those by applying advanced statistical network methods such as exponential random graph models (ERGMs) and stochastic actor-oriented models (SAOMs). Students will be able to explain and compare various network models, and develop an understanding of how those can be fit to empirical data. This will enable students to independently address research questions from various social science fields.

The following topics will be covered:

- Introduction to network models and their applications
- Stylized models:
  * uniform random graph models
  * small world models
  * preferential attachment models
- Models for testing hypotheses while controlling for the network structure:
  * Quadratic assignment procedure regression (QAP regression)
- Models for testing hypotheses on the network structure:
  * Models for one single observation of a network: exponential random graph models (ERGMs)
  * Models for panel network data: stochastic actor-oriented models (SAOMs)
  * Models for relational event data: dynamic network actor models (DynAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>W</th>
<th>Credits</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0252-15L</td>
<td>Network Analysis</td>
<td>3</td>
<td>credits</td>
<td>2V. U. Brandes</td>
</tr>
<tr>
<td>851-0585-41L</td>
<td>Computational Social Science</td>
<td>3</td>
<td>credits</td>
<td>2S. D. Helbing</td>
</tr>
</tbody>
</table>

The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

- Empirical Research and Network Data
- Macro and Micro Structure
- Centrality
- Roles
- Cohesion

Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection. Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis. In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), and (3) bridging between fundamental and applied work. Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events.

They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.
Literature

- Computational Social Science
  https://science.sciencemag.org/content/sci/323/5915/721.full.pdf
- Manifesto of Computational Social Science
  https://link.springer.com/article/10.1140/epjst/e2012-01697-8
- Social Self-Organisation
- How simple rules determine pedestrian behaviour and crowd disasters
  https://www.pnas.org/content/108/17/6884.short
- Peer review and competition in the Art Exhibition Game
  https://www.pnas.org/content/113/30/8414.short
- Generalized network dismantling
  https://www.pnas.org/content/116/14/6554.short
- Computational Social Science: Obstacles and Opportunities
  https://science.sciencemag.org/content/369/6507/1060
- Bit by Bit: Social Research in the Digital Age
  https://www.amazon.co.uk/Bit-Social-Research-Digital-Age-ebook/dp/B072MPFXX2/

Further literature will be recommended in the lectures.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Problem-solving</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

851-0586-03L | Applied Network Science: Social Media Networks | W | 3 credits | 1S | U. Brandes

Abstract

We study applications of network science methods, this semester in the domain of social media. Topics are selected for diversity in research questions and techniques for topics such as privacy and information spread on a variety of platforms. Student teams present results from the recent literature, possibly with replication, in a one-day conference.

Objective

Network science as a paradigm is entering domains from engineering to the humanities but application is tricky. By examples from recent research on social media, students learn to appreciate that, and how, context matters. They will be able to assess the appropriateness of approaches for substantive research problems, and especially when and why quantitative approaches are or are not suitable.


Abstract

Open to all Master level / PhD students.

Objective

This workshop focuses on understanding and managing the ethical and social issues arising from the integration of new technologies in various aspects of daily life.

Content

The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, news media, society, social media, digital health and justice will be then considered. These six domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explain-ability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.
## Science Research

### 851-0020-00L Gender and Science

**Type**: W  
**ECTS**: 2 credits  
**Hours**: 2V  
**Lecturers**: C. L. Blaser, M. Ligtenberg

**Abstract**

This lecture series offers an introduction to the relationship between gender and science, with a focus on the specific intersections with the sciences taught at ETH.

**Objective**

This lecture series is designed to acquaint students from all levels and departments with the various ways in which gender perspectives matter for specific scientific disciplines, as well as for science in general. Students will learn to recognize and analyse the specific ways in which scientific theories and methods are gendered, and how this connects to their own scientific disciplines.

**Content**

There is agreement across academic disciplines today that gender influences and structures the production of knowledge and that scientific knowledge production in turn shapes gender notions. Even within "hard" sciences such as mathematics, physics, engineering, etc., gender is a significant factor in determining what counts as "objective" knowledge, who can know it, what kind of knowledge is produced, and how this knowledge is acquired and justified. Feminist research aims to reveal how dominant conceptions of science and knowledge practices disadvantage women*, and other subordinate groups, with the goal of reforming these practices. An important part of feminist critique is to show that such efforts substantially improve the overall quality of research.

The semester will start with an introductory lecture acquainting students with research questions in the field of Gender and Science by summarizing its key concepts and methods. It will then continue as a series of weekly lectures, given by scholars from different scientific disciplines, that provide accessible insights into the intersection between gender studies and the guest lecturer’s research field. Students will thereby be encouraged to learn from concrete examples rather than abstract theory. The goal is for students to understand how to apply concepts and methods of gender studies to particular disciplines. A mid-term discussion session and end-term assignment will provide students the opportunity to critically reflect on how these questions are relevant for their own academic practices.

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### 851-0157-00L Mind and Brain

**Type**: W  
**ECTS**: 3 credits  
**Hours**: 2V  
**Lecturers**: M. Hagner

**Abstract**

In the last 2500 years, the mind-brain relationship has been articulated in various ways. In these lectures, I will explore the scientific and philosophical aspects of this relationship in the context of relevant cultural, historical and technological processes, with a focus on the modern neurosciences, but I will also discuss works of art and literature.

**Objective**

By the end of this lecture, students should be familiar with essential positions in the scientific and philosophical treatment of questions relating the mind to the brain. It should also become clear that some of the most relevant problems in current neurosciences have a long history.

**Content**

According to a myth, the ancient Greek philosopher Democrit dissected animals, because he was in search of the seat of the soul. Current neuroscientists use neuroimaging techniques like functional magnetic-resonance-tomography in order to localize cognitive and emotional qualities in the brain. Between these two dates lies a history of 2500 years, in which the relationship between the mind and the brain has been defined in various ways. Starting with ancient and medieval theories, the lecture will have its focus on modern theories from the nineteenth century onward. I will discuss essential issues in the history of the neurosciences such as localization theories, the neuron doctrine, reflex theory, theories of emotions, neurocybernetics and the importance of visualizing the brain and its parts, but I will also include works of art and literature.

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### Type B: Reflection About Subject-Specific Methods and Contents

**Subject-specific courses**: Recommended for doctoral, master and bachelor students (after first-year examination only). Students who already took a course within their main study program are NOT allowed to take the course again.

**These course units are also listed under "Type A", which basically means all students can enroll**

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### D-ARCH

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### 851-0703-00L Introduction to Law

**Type**: W  
**ECTS**: 2 credits  
**Hours**: 2V  
**Lecturers**: O. Streiff Gnöpff

Students who have attended or will attend the lecture "Introduction to Law for Civil Engineering and Architecture" (851-0703-03L) or "Introduction to Law" (851-0708-00L), cannot register for this course unit.

**Abstract**

This course introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.

**Objective**

Students are able to identify basic structures of the legal system. They understand selected topics of public and private law and are able to apply the fundamentals in more advanced law classes.

**Content**

Basic concepts of law, sources of law. Private law: Contract law (particularly contract for work and services), tort law, property law. Public law: Human rights, administrative law, procurement law, procedural law. Insights into the law of the EU and into criminal law.

**Lecture notes**

Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

**Literature**

Further documents will be available online (see https://laweconbusiness.ethz.ch/group/professor/stremitzer.html). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contact Design I, you will learn what the content of a contract should be so that parties can reach their goals.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Contact Design I (851-0742-00L; Fall 2021)" and enroll. The password is "ContractDesign01".

Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students

**Abstract**

This course is taught by Professor Alexander Stremitzer ([https://laweconbusiness.ethz.ch/group/professor/stremitzer.html](https://laweconbusiness.ethz.ch/group/professor/stremitzer.html)). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contact Design I, you will learn what the content of a contract should be so that parties can reach their goals.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Contact Design I (851-0742-00L; Fall 2021)" and enroll. The password is "ContractDesign01".

Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students

**Abstract**

Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.
Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design I will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These videos introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvIdf7Q0zq0). However, this course prioritizes applications of contract design.

Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Handouts, prerecorded videos, slides, and other materials

Prerequisites / notice

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.caldernherrera@uzh.ch).

851-0703-04L Law and Urban Space  W 2 credits 1V O. Streiff Gnöpff

Number of participants limited to 45

Literature

See Literature

Documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15143).

851-0707-00L Space Planning Law and Environment  W 2 credits 2G O. Bucher

Number of participants limited to: 45

Literature

Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999

Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 6.A., Bern 2016

851-0252-01L Human-Computer Interaction: Cognition and Usability  W 3 credits 2S H. Zhao, S. Credè, C. Hlöscher

Number of participants limited to 35.

Abstract

This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects.

Number of participants limited to: 35.
Objective

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course).

851-0252-08L  Evidence-Based Design: Methods and Tools For Evaluating Architectural Design

Number of participants limited to 40

Particularly suitable for students of D-ARCH

Abstract

Students are taught a variety of analytic techniques that can be used to evaluate architectural design. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

851-0175-00L  Images of the Human

3 credits  2G  J. L. Gastaldi

Abstract

This seminar will explore the multiple transformations of the conception of the “human” in the face of the current scientific, social and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad with different disciplinary backgrounds in the humanities and the social sciences.

Objective

By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

Content

The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the “human”. In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre’s lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current digital challenges. In line with the Turing Centre’s activities, the focus will be on challenges related to digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

851-0421-00L  Sapiens: A Reading Course

3 credits  2S  N. Guettler

Abstract

Yuval Noah Harari’s “Sapiens” is the most successful historical book of recent years. The seminar examines the text from a history of science perspective: What kind of sources does it rely on? What type of history is being written here? And in what tradition does “Sapiens” present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

Objective

In the course of the seminar, the students develop the competence to deal with the original text and the research literature on the history of anthropology, science and technology in a critical and historically thoughtful way. In doing so, they practise navigating independently through historical literature by means of smaller research tasks.

Content

The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the history of mankind by reading “Sapiens”. In addition to studying and critically discussing the original text, the students explore significant scientific and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of the underlying narratives and popular science genres that inform “Sapiens”.

851-0724-01L  Real Estate Property Law

3 credits  3V  M. Huser, R. Müller-Wysy, S. Stucki

Abstract

Fundamental concepts of Land Register Law and Land Surveying Law (substantive and procedural rules of Land Register Law, the parts and the relevance of the Land Register, process of registration with the Land Register, legal problems of land surveying, reform of the official land surveying).

Objective

Overview of the legal norms of land registry and surveying law.

Content

Basic principles of material and formal land registry law, components of the land register, consequences of the land register, the registration process, legal problems of surveying, the reform of official surveying, liability of the geom-eter.

Lecture notes

Abgegebene Unterlagen: Skript in digitaler Form

Literature

- Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Beiträge aus dem Institut für schweizerisches und internationales Baurecht der Universität Freiburg/Schweiz, Zürich 2014
- Meinrad Huser, Geo-Informationsrecht, Rechtlicher Rahmen für Geographische Informationssysteme, Zürich 2005
- Meinrad Huser, Darstellung von Grenzen zur Sicherung dinglicher Rechte, in ZBGR 2013, 238 ff.
### Taught competencies

#### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

#### Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

#### Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: not assessed

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**851-0467-00L**

**From Traffic Modeling to Smart Cities and Digital Democracies**

*Number of participants limited to 50.*

**Abstract**

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will reflect on the question of how democracy could be digitally upgraded to promote innovation, sustainability, and resilience.

**Objective**

To collect credit points, students will have to give a 30-40 minute presentation in the seminar, after which the presentation will be discussed. The presentation will be graded.

**Content**

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.
Further literature will be recommended in the lectures.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
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### Course Descriptions

#### 851-0742-01L Contract Design II

**Abstract**

This course is taught by Professor Alexander Stremitzer ([https://lawecon.ethz.ch/group/professors/stremitzer.html](https://lawecon.ethz.ch/group/professors/stremitzer.html)). To be considered for Contract Design II, you must have completed Contract Design I in the same semester. Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

**Prerequisites / notice**

To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

**Objective**

There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the content and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.caldaraherrera@uzh.ch).

**Content**

In 1967, Foucault showed certain entanglements of space with his concept of heterotopia; a little later, Pierre Bourdieu established a multidimensional space sociologically with his concept of field. The seminar also discusses such interweaving in current local situations and tries to think about potentials for spatial policy practice.

**Prerequisites / notice**

Cooperation in the form of discussions and scientific diary.

The additional personal work (besides the course) is about 20 working hours for the creation of a scientific journal, individual deepening and filming!

#### 850-0107-00L Science and the Public: A Problem of Mediation that the Media Have to Solve?

**Abstract**

Scientific knowledge is often provisional; it is subject to correction. That is why it cannot always satisfy the need for certainty and clarity that arises in the public as soon as political controversies are linked to questions of (scientific) knowledge. This is shown by the Corona pandemic, but not only by it.

**Objective**

Gaining insights into the relationship between the sciences, the public and the media, into their historical development and current problems.

**Content**

The feuilleton of the «Frankfurter Allgemeine Zeitung» of 27 June 2000 has gone down in the annals of recent media history. The last feuilleton of the «Frankfurter Allgemeine Zeitung» of 27 June 2000 has gone down in the annals of recent media history. These questions will be explored on some excursions into recent and also older media, scientific and cultural history.

#### 850-0101-80L Basic Problems of Environmental Ethics

**Abstract**

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distributions of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?
Objective
Participants should become familiar with basic approaches to central problems in environmental ethics.

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

Literature
Preparatory Literature


D-BAUG

Number Title Type ECTS Hours Lecturers
851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector W 2 credits 2V K. Houshang Pour Islam

Abstract
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

Prerequisites / notice
The lecture addresses students in the fields of engineering, science and other related technical fields.

851-0742-00L Contract Design I W 3 credits 2V A. Stremitzer

Abstract
This course is taught by Professor Alexander Stremitzer (https://laweconbusiness.ethz.ch/group/professor/stremitzer.html). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contact Design I, you will learn what the content of a contract should be so that parties can reach their goals.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Contract Design I (851-0742-00L; Fall 2021)" and enroll. The password is "ContractDesign01".

Number of participants limited to 160.
Max 80 ETHZ and 80 UZH Students

Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.
Objective: Agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design I will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvldfG7Ozq0). However, this course prioritizes applications of contract design. Therefore, we will use class time to discuss a selection of exciting real-world cases, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Prerequisites / notice: Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

851-0707-00L  Space Planning Law and Environment

Abstract: System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Application, legal protection, enforcement, Practical training.

Objective: Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.


Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 6.A., Bern 2016

701-0703-00L  Environmental Ethics

Abstract: The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective: On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Content: - Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarisation with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

Lecture notes: Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neill et al., Environmental Values, 2008

Generell introductions:
- Marcus Düwell et. al (Hrg.), Handbuch Ethik, 2. Auflage, Stuttgart (Metzler Verlag), 2006
- Johann S. Ach et. al (Hrg.), Grundkurs Ethik 1. Grundlagen, Paderborn (mentis) 2008

Prerequisites / notice: The procedure for accumulating CP will be explained at the start of term.

We expect participants to engage in and contribute to discussions for keeping the course interesting and lively.

052-0801-00L  Global History of Urban Design I

Abstract: This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

Objective: The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.
The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the

Yuval Noah Harari's "Sapiens" is the most successful historical book of recent years. The seminar examines the text from a history of science and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of represent a popular non-fiction book?

Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

Note: The course AI4Good is not related to Hack4Good, which is a students' initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/.

Every two weeks, each group will present ideas and progress during a short presentation followed by a discussion with all course members. At the end of the course, students will present their final results and submit source code. In addition, they will describe the developed method in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.


A list of further recommended literature will be found within each chapter of the reader (Skript).

Students with a strong background in machine learning and excellent programming skills (preferably in Python)

The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe

Students with a strong background in machine learning and excellent programming skills (preferably in Python).

Prerequisites / notice

Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

Prerequisites / notice

Students with a strong background in machine learning and excellent programming skills (preferably in Python)
**Taught competencies**

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

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: not assessed

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**851-0742-01L Contract Design II**

**Title**: Contract Design II  
**Type of Course**: W  
**ECTS**: 1  
**Hours**: 1U  
**Lecturer**: A. Stremitzer  
**Prerequisites / notice**: Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract. Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

**Course Information**: To be considered for Contract Design II, you must have completed Contract Design I in the same semester. Students can only register for Contract Design II after obtaining approval by Prof. Stremitzer.

**Abstract**: Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract. Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

**Objective**: There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the content and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

**Prerequisites / notice**: To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

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**851-0101-80L Basic Problems of Environmental Ethics**

**Title**: Basic Problems of Environmental Ethics  
**Type of Course**: W  
**ECTS**: 3  
**Hours**: 2G  
**Lecturer**: L. Wingert  
**Prerequisites / notice**: Particularly suitable for students of D-BIOL, D-CHAB, D-HEST

**Abstract**: Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?

**Objective**: Participants should become familiar with basic approaches to central problems in environmental ethics.

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of “climate justice”.

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

**Literature**:  

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**D-BIOL**

**851-0180-00L Research Ethics**

**Title**: Research Ethics  
**Type of Course**: W  
**ECTS**: 2  
**Hours**: 2G  
**Lecturer**: G. Achermann, P. Emch  
**Prerequisites / notice**: Particularly suitable for students of D-BIOL, D-CHAB, D-HEST

**Abstract**: Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

**Objective**: Participants of the course Research Ethics will  
- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;  
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;
I. Introduction to Moral Reasoning

1. Ethics - the basics
   1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
   2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
   3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities

1. Integrity in research and research misconduct
   1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
   2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
   3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities

1. Research involving human subjects
   1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
   2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

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3. Dual use research
   3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Prerequisites / notice

What are the requirements?

First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more...).

Taught competencies

Domain A - Subject-specific Competencies
   Concepts and Theories assessed

Domain B - Method-specific Competencies
   Analytical Competencies assessed
   Decision-making assessed
   Problem-solving assessed

Domain C - Social Competencies
   Communication assessed
   Cooperation and Teamwork assessed

Domain D - Personal Competencies
   Creative Thinking assessed
   Critical Thinking assessed
   Integrity and Work Ethics assessed
   Self-awareness and Self-reflection assessed

Lecture notes

Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector

Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT

Abstract

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.
Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

Prerequisites /

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Abstract
This course introduces students to legal, economic, and social perspectives on the increasing economic and social importance of technology. We focus particularly on the challenges to current law posed by the increasing rate of tech innovation and adoption generally and also by case-specific features of prominent near-future technologies.

Objective
The course is intended for a wide range of engineering students, from machine learning to bioengineering to human computer interaction, as well as for law students interested in acquiring a better understanding of state-of-the-art technology.

The course will combine both an overview of major areas of law that affect the regulation of technology and also guest lectures on the state-of-the art in a variety of important technologies, ranging from autonomous vehicles to fair artificial intelligence to consumer-facing DNA technologies.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.
Content

The planned course outline is below

1. Overview of science, law, and technology
   a. Studies of law and technology
   b. Should science be regulated, and if so, how?
   c. Technology as a social problem

2. Designing technology for humans
   a. Attention fiduciaries and the digital environment
   b. Does technology weaponize known problems of bounded human rationality?
   c. Should technology be regulated as a psychotropic substance? An addictive substance?
   d. Can technology make life easier?
   e. Psychological effects of surveillance

3. Governing tech
   a. Can small governments regulate big tech?
   b. National and supranational legislation
   c. Enforcing the law with technology
   d. Can enforcement be baked into technology?

4. AI and fairness
   a. Discrimination
   b. Privacy
   c. Opacity
   d. AI and due process

5. Trade secret and technological litigation
   a. Trade secret is a long-standing tool for litigation but does it enjoy too much deference?
   b. Trade secrets and the rights of employees

6. Enforcement against tech
   a. Big tech and antitrust
   b. Consumer protection

7. The Digital Battlefield
   a. Technology for spying
   b. Spying on technology companies
   c. Race to be AI superpower
   d. Immigration policy

8. Contract law
   a. Smart contracts
   b. Modernizing contract law and practice
   c. Regulating cryptocurrencies

9. Tort law
   a. Applying existing tort law to new autonomous technologies
   b. Personhood and personal responsibility
   c. Victim entitlements

10. Self-driving cars and other autonomous robotics
    a. Legal regimes
    b. Diversity in morality judgements related to autonomous vehicles

11. Biometrics
    a. Widespread use of facial recognition
    b. Law enforcement
    c. Connecting biometrics to social data
    d. Solving crimes with biometrics

12. New Biology and Medicine
    a. Unregulated science (biohackers)
    b. Promising technology before it can be delivered
    c. Connecting medicine to social data
    d. Using technology to circumvent medical regulations

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851-0175-00L Images of the Human W 3 credits 2G J. L. Gastaldi

Abstract

This seminar will explore the multiple transformations of the conception of the “human” in the face of the current scientific, social, and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences.

Objective

By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

Content

The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the “human”. In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre's activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

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851-0101-80L Basic Problems of Environmental Ethics W 3 credits 2G L. Wingert

Abstract

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distributions of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?
Objective

Participants should become familiar with basic approaches to central problems in environmental ethics.

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

Preparatory Literature


851-0594-04L One Study, Two Paths: The Dual-Use Dilemma in the Life Sciences

Particularly suitable for students (from Bachelor 3rd year onwards) of D-BIOL, D-CHAB, D-HEST

Maximum number of participants limited to 20

Abstract

Research and technologies emerging from the life sciences bring beneficial aspects to our society but also unforeseeable risks regarding biosafety and biosecurity. In this course, students will learn about the advances in science and technology and their implications for society and international treaties (BWC or CWC) and their social, ethical and legal responsibilities as life scientists.

By the end of this course, students will be able to critically assess their own research regarding the possibility to apply scientific results or methods with benevolent or malevolent intentions (dual-use) and will be able to integrate strategies into their research design to reduce the misuse potential.

Content

Life sciences evolve rapidly supported by developments in related disciplines. However, while those new and emerging technologies greatly benefit society, they additionally bring along predictable as well as unforeseeable risks in the context of biosafety and biosecurity.

The ability of life science professionals to critically assess their own research regarding potential misuse risks and how to reduce these is a crucial aspect to maintain research integrity against the background of novel security concerns arising from the speed and dynamics of advancements in the life- and associated sciences.

During the course, you will discuss about your societal, ethical, and legal responsibilities as life scientists. You will become aware of biosafety and biosafety risks and what scientists can do to minimize misuse potential in highest-risk research (="dual use research of concern"). A strong focus of the seminar lies on interactive group work for which you will be able to build on your individual experiences and scientific background. Additionally, a combination of lectures and input from guest speakers will provide you with essential background information and insights into real-world applications. You will understand the dual-use dilemma and learn about biological warfare, biological terrorism, and the international prohibition regimes; the national implementation of the biological and toxins weapons convention and about efforts to build the web of prevention against the misuse of life sciences.

Objective

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

The lecture addresses students in the fields of engineering, science and other related technical fields.

851-0175-00L Images of the Human

W 3 credits 2G J. L. Gastaldi

Abstract

This seminar will explore the multiple transformations of the conception of the "human" in the face of the current scientific, social and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences.

Objective

By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the "human". In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre's activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

**Basic Problems of Environmental Ethics**

**Abstract**

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?

**Objective**

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

**Literature**

Preparatory Literature

2. Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction should be so that parties can reach their goals. First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!): 1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!).

3. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more...). You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for "Contract Design I (851-0742-00L; Fall 2021)" and enroll. The password is "ContractDesign01".

Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students

Abstract

Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.
Objective

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design II will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvldfG7ozqO). However, this course prioritizes applications of contract design.

Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Hands-on exercises, case studies, group work, presentations, and final project.

Lecture notes

Prerequisites / notice

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GEES. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFO, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderraherra@uzh.ch).

Objective

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

Abstract

The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

851-0738-00L Intellectual Property: Introduction

W 2 credits
2V M. Schweizer

Particularly suitable for students of D-CHAB, D-INFO, D-ITET, D-MAVT, D-MATL, D-MTEC

851-0738-01L The Role of Intellectual Property in the Engineering and Technical Sector

W 2 credits
2V K. Houshang Pour Islam

Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT

Abstract

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

851-0742-01L Contract Design II

W 1 credit
1U A. Stremitzer

This course is taught by Professor Alexander Stremitzer (https://law econ.ethz.ch/group/professors/stremitzer.html).

To be considered for Contract Design II, you must have completed Contract Design I in the same semester. Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

Abstract

Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract.

Objective

There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the content and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderraherra@uzh.ch).

Prerequisites / notice

To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

851-0125-65L A Sampler of Histories and Philosophies of

W 3 credits
2V R. Wagner

This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

**Abstract**

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

**Objective**

Participants should become familiar with basic approaches to central problems in environmental ethics. Maximum number of participants limited to 20

**Preparatory Literature**


**Literature**

Given a specific problem in global development, students shall learn to self-responsibly design, implement and experimentally evaluate a suitable solution. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members.

The AI4Good course is a hackathon turned into a full course. At the beginning of the course, stakeholders (e.g., NGOs) active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members. The AI4Good course is a hackathon turned into a full course. At the beginning of the course, stakeholders (e.g., NGOs) active in the development sector will describe several problems that could be solved with a machine learning approach. Organizers of the course will make sure that only those problems are selected that are suitable for a machine learning approach and where sufficient amounts of data (and labels) are available. Students will organize themselves into small groups of 3-5 students, where each group works on solving a specific problem. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Every two weeks, each group will present ideas and progress during a short presentation followed by a discussion with all course members. At the end of the course, students will present their final results and submit source code. In addition, they will describe the developed method in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.

Note: The course AI4Good is not related to Hack4Good, which is a students’ initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>851-0650-00L AI4Good</th>
<th>3 credits</th>
<th>2G</th>
<th>J. D. Wegner</th>
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</thead>
<tbody>
<tr>
<td>Objective</td>
<td>The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members.</td>
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<tr>
<td>Content</td>
<td>Given a specific problem in global development, students shall learn to self-responsibly design, implement and experimentally evaluate a suitable solution. Students will also learn to critically evaluate their ideas and solutions together with all course members in a broader context that go beyond mere technical solutions, but touch on ethics, local culture etc., too.</td>
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<tr>
<td>Literature</td>
<td>Students with a strong background in machine learning and excellent programming skills (preferably in Python)</td>
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<tr>
<th>Prerequisites / notice</th>
<th>851-0421-00L Sapiens: A Reading Course</th>
<th>3 credits</th>
<th>2S</th>
<th>N. Guettler</th>
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<tr>
<td>Objective</td>
<td>In the course of the seminar, the students develop the competence to deal with the original text and the research literature on the history of anthropology, science and technology in a critical and historically thoughtful way. In doing so, they practise navigating independently through historical literature by means of smaller research tasks.</td>
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<tr>
<td>Content</td>
<td>The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the history of mankind by reading &quot;Sapiens&quot;. In addition to studying and critically discussing the original text, the students explore significant scientific and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of the underlying narratives and popular science genres that inform &quot;Sapiens&quot;.</td>
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<tr>
<td>Literature</td>
<td>Yuval Noah Harari's &quot;Sapiens&quot; is the most successful historical book of recent years. The seminar examines the text from a history of science perspective: What kind of sources does it rely on? What type of history is being written here? And in what tradition does &quot;Sapiens&quot; represent a popular non-fiction book?</td>
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<tr>
<td>Preparatory Literature</td>
<td>Preparatory literature (and labels) are available. Students will organize themselves into small groups of 3-5 students, where each group works on solving a specific problem. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Every two weeks, each group will present ideas and progress during a short presentation followed by a discussion with all course members. At the end of the course, students will present their final results and submit source code. In addition, they will describe the developed method in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.</td>
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<th>Prerequisites / notice</th>
<th>851-0101-80L Basic Problems of Environmental Ethics</th>
<th>3 credits</th>
<th>2G</th>
<th>L. Wingert</th>
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<td>Objective</td>
<td>Participants should become familiar with basic approaches to central problems in environmental ethics.</td>
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<tr>
<td>Content</td>
<td>The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms). Another focus will be to clarify the concept of &quot;climate justice&quot;.</td>
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<tr>
<td>Literature</td>
<td>Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distributions of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?</td>
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<tr>
<th>Prerequisites / notice</th>
<th>851-0180-00L Research Ethics</th>
<th>2 credits</th>
<th>2G</th>
<th>G. Achermann, P. Emch</th>
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<tbody>
<tr>
<td>Objective</td>
<td>Particularly suitable for students of D-BIOL, D-CHAB, D-HEST</td>
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<tr>
<td>Abstract</td>
<td>Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.</td>
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<tr>
<td>Objective</td>
<td>Participants of the course Research Ethics will: • Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research; • Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kind of ethical problems a scientist is likely to encounter;</td>
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Introduction to Health Economics and Policy

1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism); 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity
1.5 Selection of study participants – the concept of vulnerability
1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions: a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g. taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed

363-1027-00L Introduction to Health Economics and Policy

W 2 credits 1V C. Wibel

Abstract
Health expenditures constitute about 10% of GDP in OECD countries. Extensive government intervention is a typical feature in health markets. Risk factors to health have been changing with growing importance of lifestyle factors such as smoking, obesity and lack of physical activity. This course gives an introduction to the economic concepts and empirical findings in health economics.

Objective
Introduce students without prior economic background to the main concepts of health economics and policy to enhance students understanding of how health care institutions and markets function.

Content
The course gives an introduction to the economic concepts and empirical findings in health economics to enhance students understanding of how health care institutions and markets function. Motivated by the fact that health care markets are designed differently across countries, this course looks at the challenges in regulating health care markets. First, two important decisions of individuals will be analyzed: What types and amount of personal health care services does an individual demand? How much will health insurance coverage be purchased? In the second part, the supply side of health care markets will be discussed. What are the financial incentives of physicians, and how do these influence physicians' treatment choices? What does it mean and imply that a physician is an agent for a patient? The choices made by societies about how health care services are financed and about the types of organizations that supply health care will be addressed in the third part. One important choice is whether a country will rely on public financing of personal health care services or encourage private health insurance markets. How could and should a public health insurance system be designed? The advantages and disadvantages of the alternatives will be discussed to provide a framework for analyzing specific types of health care systems.
While being the universal constant which is common to every human being in history, the body is also culturally and historically specific. In various aspects of daily life, students learn the history of the body from mid-eighteenth century onwards through examples taken from the multidisciplinary scholarship on the history of science in anthropology, prehistory and popular science literature on the human body. The seminar aims to introduce students to the history of science in anthropology, prehistory and popular science literature on the human body, and make them mindful of the multiple ways in which understanding the body and its relationship with culture and power can help think critically of the present we live in.

The workshop offers students an experience that trains their ability for critical analysis and develops awareness of responsibilities as a researcher, consumer and citizen. Learning will occur in the context of three intensive workshop days, which are highly interactive and focus on the development and application of reasoning skills.

The workshop will begin with some fundamentals: the nature of ethics, of consent and big data, of AI ethics, public trust and health ethics. Students will then be introduced to key ethical concepts such as fairness, autonomy, trust, accountability, justice, as well different ways of reasoning about the ethics of digital technologies.

A range of practical problems and issues in the domains of education, news media, society, social media, digital health and justice will be then considered. These six domains are represented respectively by unique and interesting case studies. Each case study has been selected not only for its timely and engaging nature, but also for its relevance. Through the analysis of these case studies key ethical questions (such as fairness, accountability, explain-ability, access etc.) will be highlighted and questions of responsibility and tools for ethical practice will be explored. Throughout, the emphasis will be on learning to make sound arguments about the ethical aspects of policy, practice and research.

The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the human body that challenge scientific understandings of it as an unchanging biological entity. By adopting a humanities perspective on topics like anatomy and surgery, the treatment of the insane, sexuality, physical culture, eugenics, and body productivity, the course looks at shifting attitudes to body health and fitness and the ways these have been shaped by considerations of gender, race, and class as well as by socioeconomic circumstances of modernity. It considers how bodies have historically concerned governments who have classified different (sections of) populations as ‘fit’ or ‘unfit’ to be members of a certain community.

The ‘long durée’ approach of the course allows to consider the continuities and changes in terms of scientific epistemologies and practices regarding the body. In doing so, debated contemporary issues such as assisted reproductive technologies and wearable systems of surveillance of the worker fatigue in the workplace are discussed.

In the seminar we examine how ideas of the body have changed throughout history and how these ideas of the body can be useful to understand political, social, and cultural phenomena in particular historical settings.

The course is structured thematically, adopts a multidisciplinary approach, and uses academic texts as well as concrete examples. It intends to a) enable STEM students to develop new perspectives on their core subjects by bringing them in dialogue with the themes dealt with and by raising ethical questions; b) familiarize students in general with major topics in the field of the recent scholarship on the body and make them mindful of the multiple ways in which understanding the body and its relationship with culture and power can help think critically of the present we live in.
Research and technologies emerging from the life sciences bring beneficial aspects to our society but also unforeseeable risks regarding biosafety and biosecurity. In this course, students will learn about the advances in science and technology and their implications for society and international treaties (BWC or CWC) and their social, ethical and legal responsibilities as life scientists.

By the end of this course, students will be able to critically assess their own research regarding the possibility to apply scientific results or methods with benevolent or malevolent intentions (dual-use) and will be able to integrate strategies into their research design to reduce the misuse potential.

Life sciences evolve rapidly supported by developments in related disciplines. However, while those new and emerging technologies greatly benefit society, they additionally bring along predictable as well as unforeseeable risks in the context of biosafety and biosecurity.

During the course, you will discuss about your societal, ethical, and legal responsibilities as life scientists. You will become aware of biosafety and biosecurity risks and what scientists can do to minimize misuse potential in highest-risk research (=dual use research of concern”). A strong focus of the seminar lies on interactive group work for which you will be able to build on your individual experiences and scientific background. Additionally, a combination of lectures and input from guest speakers will provide you with essential background information and insights into real-world applications. You will understand the dual-use dilemma and learn about biological warfare, biological terrorism, and the international prohibition regimes; the national implementation of the biological and toxins weapons convention and about efforts to build the web of prevention against the misuse of life sciences.

## D-INFK

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<th>Number</th>
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<td>851-0252-01L</td>
<td>Human-Computer Interaction: Cognition and Usability</td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>H. Zhao, S. Credé, C. Hölscher</td>
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**Abstract**

This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects.

**Objective**

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course).

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<tr>
<td>851-0742-00L</td>
<td>Contract Design I</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>A. Stremitzer</td>
</tr>
</tbody>
</table>

**Abstract**

This course is taught by Professor Alexander Stremitzer (https://laweconbusiness.ethz.ch/group/professor/stremitzer.html). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contract Design I, you will learn what the content of a contract should be so that parties can reach their goals.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2021)” and enroll. The password is “ContractDesign01”.

Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students

**Number of participants limited to 20**

**Abstract**

One Study, Two Paths: The Dual-Use Dilemma in the Life Sciences

Particularly suitable for students (from Bachelor 3rd year onwards) of D-BIOL, D-CHAB, D-HEST

Maximum number of participants limited to 20

**Objective**

By the end of this course, students will be able to critically assess their own research regarding the possibility to apply scientific results or methods with benevolent or malevolent intentions (dual-use) and will be able to integrate strategies into their research design to reduce the misuse potential.

**Content**

Life sciences evolve rapidly supported by developments in related disciplines. However, while those new and emerging technologies greatly benefit society, they additionally bring along predictable as well as unforeseeable risks in the context of biosafety and biosecurity.

During the course, you will discuss about your societal, ethical, and legal responsibilities as life scientists. You will become aware of biosafety and biosecurity risks and what scientists can do to minimize misuse potential in highest-risk research (=dual use research of concern”). A strong focus of the seminar lies on interactive group work for which you will be able to build on your individual experiences and scientific background. Additionally, a combination of lectures and input from guest speakers will provide you with essential background information and insights into real-world applications. You will understand the dual-use dilemma and learn about biological warfare, biological terrorism, and the international prohibition regimes; the national implementation of the biological and toxins weapons convention and about efforts to build the web of prevention against the misuse of life sciences.

## Literature


851-0742-00L One Study, Two Paths: The Dual-Use Dilemma in the Life Sciences

Particularly suitable for students (from Bachelor 3rd year onwards) of D-BIOL, D-CHAB, D-HEST

Number of participants limited to 35.

851-0252-01L Human-Computer Interaction: Cognition and Usability

Number of participants limited to 35.

851-0742-00L Contract Design I

This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects.

## Objective

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course).

Number of participants limited to 160. Max 80 ETHZ and 80 UZH Students

**Abstract**

Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.

**Objective**

By the end of this course, students will be able to critically assess their own research regarding the possibility to apply scientific results or methods with benevolent or malevolent intentions (dual-use) and will be able to integrate strategies into their research design to reduce the misuse potential.

**Content**

Life sciences evolve rapidly supported by developments in related disciplines. However, while those new and emerging technologies greatly benefit society, they additionally bring along predictable as well as unforeseeable risks in the context of biosafety and biosecurity.

During the course, you will discuss about your societal, ethical, and legal responsibilities as life scientists. You will become aware of biosafety and biosecurity risks and what scientists can do to minimize misuse potential in highest-risk research (=dual use research of concern”). A strong focus of the seminar lies on interactive group work for which you will be able to build on your individual experiences and scientific background. Additionally, a combination of lectures and input from guest speakers will provide you with essential background information and insights into real-world applications. You will understand the dual-use dilemma and learn about biological warfare, biological terrorism, and the international prohibition regimes; the national implementation of the biological and toxins weapons convention and about efforts to build the web of prevention against the misuse of life sciences.

## Literature

Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design I will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvldG70zqlQ). However, this course prioritizes applications of contract design. Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Handouts, prerecorded videos, slides, and other materials

Perquisites / notice
Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer's Teaching Assistant Diego Caldera (diegoalberto.calderraherra@uzh.ch).

851-0727-02L E-Business-Law

W 2 credits 2V

D. Rosenthal

Objective

The objective is knowing and understanding key legal concepts relevant for doing e-business, in particularly understanding how e-business is regulated by law nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications.

Content

Vorgesehene Strukturierung der Vorlesung:

1) Welches Recht gilt im E-Business?
   - Internationalität des Internets
   - Regulierte Branchen

2) Gestaltung und Vermarktung von E-Business-Angeboten
   - Verwendung fremder und Schutz der eigenen Inhalte
   - Haftung im E-Business (und wie sie beschränkt werden kann)
   - Domain-Namen

3) Beziehung zu E-Business-Kunden
   - Verträge im E-Business, Konsumentenschutz
   - Elektronische Signaturen
   - Datenschutz
   - Spam

4) Verträge mit E-Business-Providern

Änderungen, Umstellungen und Kürzungen bleiben vorbehalten. Der aktuelle Termin- und Themenplan ist zu gegebener Zeit über die elektronische Dokumentenablage abrufbar.

851-0738-00L Intellectual Property: Introduction

W 2 credits 2V

M. Schweizer

Objective

The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights).

Abstract

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

851-0252-13L Network Modeling

W 3 credits 2V

C. Stadtfeld, V. Amati

Students are required to have basic knowledge in...
Network science is a distinct domain of data science that focuses on relational systems. Various models have been proposed to describe structures and dynamics of networks. Statistical and numerical methods have been developed to fit these models to empirical data. Emphasis is placed on the statistical analysis of (social) systems and their connection to social theories and data sources.

**Objective**

Students will be able to develop hypotheses that relate to the structures and dynamics of (social) networks, and tests those by applying advanced statistical network methods such as exponential random graph models (ERGMs) and stochastic actor-oriented models (SAOMs). Students will be able to explain and compare various network models, and develop an understanding of how those can be fit to empirical data. This will enable students to independently address research questions from various social science fields.

**Content**

The following topics will be covered:

- Introduction to network models and their applications
  - Stylized models:
    - uniform random graph models
    - small world models
    - preferential attachment models
  - Models for testing hypotheses while controlling for the network structure:
    - Quadratic assignment procedure regression (QAP regression)
  - Models for testing hypotheses on the network structure:
    - Models for one single observation of a network: exponential random graph models (ERGMs)
    - Models for panel network data: stochastic actor-oriented models (SAOMs)
    - Models for relational event data: dynamic network actor models (DynAMs)

The application of these models is illustrated through examples and practical sessions involving the analysis of network data using the software R.

**Lecture notes**

Slides and lecture notes are distributed via the associated course moodle.

**Literature**


**Prerequisites / notice**

Students are required to have basic knowledge in inferential statistics and should be familiar with linear and logistic regression models.
# Content

The planned course outline is below

1. Overview of science, law, and technology
   a. Studies of law and technology
   b. Should science be regulated, and if so, how?
   c. Technology as a social problem

2. Designing technology for humans
   a. Attention fiduciaries and the digital environment
   b. Does technology weaponize known problems of bounded human rationality?
   c. Should technology be regulated as a psychotropic substance? An addictive substance?
   d. Can technology make life easier?
   e. Psychological effects of surveillance

3. Governing tech
   a. Can small governments regulate big tech?
   b. National and supranational legislation
   c. Enforcing the law with technology
   d. Can enforcement be baked into technology?

4. AI and fairness
   a. Discrimination
   b. Privacy
   c. Opacity
   d. AI and due process

5. Trade secret and technological litigation
   a. Trade secret is a long-standing tool for litigation but does it enjoy too much deference?
   b. Trade secrets and the rights of employees

6. Enforcement against tech
   a. Big tech and antitrust
   b. Consumer protection

7. The Digital Battlefield
   a. Technology for spying
   b. Spying on technology companies
   c. Race to be AI superpower
   d. Immigration policy

8. Contract law
   a. Smart contracts
   b. Modernizing contract law and practice
   c. Regulating cryptocurrencies

9. Tort law
   a. Applying existing tort law to new autonomous technologies
   b. Personhood and personal responsibility
   c. Victim entitlements

10. Self-driving cars and other autonomous robotics
    a. Legal regimes
    b. Diversity in morality judgements related to autonomous vehicles

11. Biometrics
    a. Widespread use of facial recognition
    b. Law enforcement
    c. Connecting biometrics to social data
    d. Solving crimes with biometrics

12. New Biology and Medicine
    a. Unregulated science (biohackers)
    b. Promising technology before it can be delivered
    c. Connecting medicine to social data
    d. Using technology to circumvent medical regulations

## 851-0101-86L Complex Social Systems: Modeling Agents, Learning, W and Games

<table>
<thead>
<tr>
<th>Credits</th>
<th>3</th>
<th>Semester</th>
<th>2S</th>
<th>N. Antulov-Fantulin, T. Asikis, D. Helbing</th>
</tr>
</thead>
</table>

Number of participants limited to 100.

Prerequisites: Basic programming skills, elementary probability and statistics.

**Abstract**

This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.

**Objective**

The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically.

The students should be able to implement simulation models and document their skills through a seminar thesis and finally give a short oral presentation.

**Content**

Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.
### Literature

- **Agent-Based Modeling**
  - [Link](https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2)

- **Social Self-Organization**
  - [Link](https://www.springer.com/gp/book/9783642240034)

- **Traffic and related self-driven many-particle systems**
  - [Reviews of Modern Physics 73, 1067](https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067)

- **An Analytical Theory of Traffic Flow (collection of papers)**
  - [Link](https://www.researchgate.net/publication/261629187)

- **Pedestrian, Crowd, and Evacuation Dynamics**
  - [Link](https://www.research-collection.ethz.ch/handle/20.500.11850/45424)

- **The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)**
  - [Link](https://science.sciencemag.org/content/342/6164/1337)

Further literature will be recommended in the lectures.

### Prerequisites / notice

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
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<td>Techniques and Technologies</td>
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<tr>
<td></td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</table>

### Content

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

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### Building a Robot Judge: Data Science for Decision-Making (Course Project)

**Abstract**

Students investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. This is the extra credit for a larger course project for the course.

**Objective**

In a semester paper, students (individually or in groups) will conceive and implement their own research project applying natural language tools to legal texts. Some programming experience in Python is required, and some experience with NLP is highly recommended.
Students will investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. We will use these predictions to better understand the operation of the legal system. In a semester project, student groups will conceive and implement a research design for examining this type of empirical research question.
Literature

Martin Treiber and Arne Kesting
Traffic Flow Dynamics: Data, Models and Simulation

Dirk Helbing
Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

Dirk Helbing
An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Michael Batty, Kay Axhausen et al.
Smart cities of the future

Books by Michael Batty
https://link.springer.com/article/10.1140/epjst/e2012-01703-3

How social influence can undermine the wisdom of crowd effect
https://www.pnas.org/content/108/22/2020

Evidence for a collective intelligence factor in the performance of human groups
https://science.sciencemag.org/content/330/6004/886.full

Optimal incentives for collective intelligence
https://www.pnas.org/content/114/20/5077.short

Collective Intelligence: Creating a Prosperous World at Peace
https://www.amazon.com/Collective-Intelligence-Creating-Prosperous-World/dp/097156616X/

Big Mind: How Collective Intelligence Can Change Our World
https://www.amazon.com/Big-Mind-Collective-Intelligence-Change/dp/0691170797/

Programming Collective Intelligence
https://www.amazon.com/Programming-Collective-Intelligence-Building-Applications/dp/0596529325/

Urban architecture as connective-collective intelligence. Which spaces of interaction?
https://www.mdpi.com/2071-1050/5/7/2928

Build digital democracy
https://www.nature.com/news/society-build-digital-democracy-1.18690

How to make democracy work in the digital age
http://www.huffingtonpost.com/entry/how-to-make-democracy-work-in-the-digital-age_us_57a2f48e4b0456cb7e17e0f

Digital Democracy: How to make it work?
http://futurict.blogspot.com/2020/06/digital-democracy-how-to-make-it-work.html

Proof of witness presence: Blockchain consensus for augmented democracy in smart cities

Iterative Learning Control for Multi-agent Systems Coordination
https://www.amazon.co.uk/Iterative-Learning-Control-Multi-agent-Coordination-ebook/dp/B06XJVQC41/ref=sr_1_1_fkmr1?dchild=1&keywords=coordination+Jennings+multi-agent&qid=1601973480&sr=8-1-fkmr1

Decentralized Collective Learning for Self-managed Sharing Economies
https://dl.acm.org/doi/abs/10.1145/3277688

Further literature will be recommended in the lectures.

Autumn Semester 2021
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

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851-0125-65L A Sampler of Histories and Philosophies of Mathematics
- Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS

Abstract This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

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860-0023-00L International Environmental Politics
- Particularly suitable for students D-ITET, D-USYS

Abstract This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

Objective The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

Content This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:
1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit),

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Lecture notes Assigned reading materials and slides will be available via Moodle.

Literature Assigned reading materials and slides will be available via Moodle.
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<table>
<thead>
<tr>
<th>Course Code</th>
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<td>851-0252-01L</td>
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**Objective**

**Prerequisites / notice**

**Abstract**

The course deals with the basic legal framework for doing e-business as well as using information technology. It discusses a variety of legal concepts and rules to be taken into account in practice, be it when designing and planning new media business models, be it when implementing online projects and undertaken information technology activities.

The objective is knowing and understanding key legal concepts relevant for doing e-business, in particularly understanding how e-business is regulated by law nationally and internationally, how contracts are concluded and performed electronically, which rules have to be obeyed in particular in the Internet with regard to third party and own content and client data, the concept of liability applied in e-business and the role of the law in the practical implementation and operation of e-business applications.

The seminar will introduce theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects.

This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g. user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course).

The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.

The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall be familiar with the issues of corporate compliance, i.e. the system to ascertain that all legal and ethical rules are observed.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

A comprehensive script will be made available online on the moodle platform.
The Role of Intellectual Property in the Engineering and Technical Sector
Particularly suitable for students of D-BAUG, D-BIOL, D-BSSE, D-CHAB, D-ITET, D-MAVT

Abstract
The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Objective
In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and distribution and in research and development, they are increasingly being confronted with questions concerning the patenting of technical inventions and the use of patent information.

The lecture will acquaint participants with practical aspects of intellectual property and enable them to use the acquired knowledge in their future professional life.

Topics covered during the lecture will include:
- The importance of innovation in industrialised countries
- An overview of the different forms of intellectual property
- The protection of technical inventions and how to safeguard their commercialisation
- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

Case studies will illustrate and deepen the topics addressed during the lecture.

Prerequisites / notice
The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

Particularly suitable for students of D-CHAB, D-INFK, D-ITET, D-MAVT, D-MATL, D-MTEC

Abstract
The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

Objective
The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

Number of participants limited to 30.

Abstract
This course introduces students to legal, economic, and social perspectives on the increasing economic and social importance of technology. We focus particularly on the challenges to current law posed by the increasing rate of tech innovation and adoption generally and also by case-specific features of prominent near-future technologies.

Objective
The course is intended for a wide range of engineering students, from machine learning to bioengineering to human computer interaction, as well as for law students interested in acquiring a better understanding of state-of-the-art technology.

The course will combine both an overview of major areas of law that affect the regulation of technology and also guest lectures on the state-of-the-art in a variety of important technologies, ranging from autonomous vehicles to fair artificial intelligence to consumer-facing DNA technologies.

The course is open to ETH students through the Science in Perspective program of the Department of Humanities, Social and Political Sciences.
The planned course outline is below

1. Overview of science, law, and technology
   a. Studies of law and technology
   b. Should science be regulated, and if so, how?
   c. Technology as a social problem

2. Designing technology for humans
   a. Attention fiduciaries and the digital environment
   b. Does technology weaponize known problems of bounded human rationality?
   c. Should technology be regulated as a psychotropic substance? An addictive substance?
   d. Can technology make life easier?
   e. Psychological effects of surveillance

3. Governing tech
   a. Can small governments regulate big tech?
   b. National and supranational legislation
   c. Enforcing the law with technology
   d. Can enforcement be baked into technology?

4. AI and fairness
   a. Discrimination
   b. Privacy
   c. Opacity
   d. AI and due process

5. Trade secret and technological litigation
   a. Trade secret is a long-standing tool for litigation but does it enjoy too much deference?
   b. Trade secrets and the rights of employees

6. Enforcement against tech
   a. Big tech and antitrust
   b. Consumer protection

7. The Digital Battlefield
   a. Technology for spying
   b. Spying on technology companies
   c. Race to be AI superpower
   d. Immigration policy

8. Contract law
   a. Smart contracts
   b. Modernizing contract law and practice
   c. Regulating cryptocurrencies

9. Tort law
   a. Applying existing tort law to new autonomous technologies
   b. Personhood and personal responsibility
   c. Victim entitlements

10. Self-driving cars and other autonomous robotics
    a. Legal regimes
    b. Diversity in morality judgements related to autonomous vehicles

11. Biometrics
    a. Widespread use of facial recognition
    b. Law enforcement
    c. Connecting biometrics to social data
    d. Solving crimes with biometrics

12. New Biology and Medicine
    a. Unregulated science (biohackers)
    b. Promising technology before it can be delivered
    c. Connecting medicine to social data
    d. Using technology to circumvent medical regulations

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**851-0101-86L Complex Social Systems: Modeling Agents, Learning, and Games**

**W and GameS**

3 credits 2S N. Antulov-Fantulin, T. Asikis, D. Helbing

- **Number of participants limited to 100.**
- **Prerequisites:** Basic programming skills, elementary probability and statistics.
- **Abstract**
  This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.
- **Objective**
  The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically.
  
  The students should be able to implement simulation models and document their skills through a seminar thesis and finally give a short oral presentation.

- **Content**
  Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

  Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.
Lecture notes
The lecture slides will be presented on the course web page after each lecture.

Agent-Based Modeling
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization

Traffic and related self-driven many-particle systems
https://journals.aps.org/revmodphys/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629167

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

Further literature will be recommended in the lectures.

Prerequisites / notice
The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain B - Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management assessed

Domain C - Social Competencies

- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation not assessed
- Leadership and Responsibility assessed
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity assessed
- Negotiation not assessed

Domain D - Personal Competencies

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

851-0760-00L Building a Robot Judge: Data Science for Decision-Making
Particularly suitable for students of D-INFK, D-ITET, D-MTEC

W 3 credits 2V E. Ash

Abstract
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.

Content
Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

851-0761-00L Building a Robot Judge: Data Science for Decision-Making (Course Project)
This is the optional course project for "Building a Robot Judge: Data Science for the Law."

W 2 credits 2V E. Ash

Abstract
Students investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. This is the extra credit for a larger course project for the course.

Objective
In a semester paper, students (individually or in groups) will conceive and implement their own research project applying natural language tools to legal texts. Some programming experience in Python is required, and some experience with NLP is highly recommended.
Students will investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. We will use these predictions to better understand the operation of the legal system. In a semester project, student groups will conceive and implement a research design for examining this type of empirical research question.

#### 851-0650-00L  AI4Good  W  3 credits  2G  J. D. Wegner

**Abstract**
The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members.

**Objective**
Given a specific problem in global development, students shall learn to self-responsibly design, implement and experimentally evaluate a suitable solution. Students will also learn to critically evaluate their ideas and solutions together with all course members in a broader context that go beyond mere technical solutions, but touch on ethics, local culture etc., too.

**Content**
The AI4Good course is a hackathon turned into a full course. At the beginning of the course, stakeholders (e.g., NGOs) active in the development sector will describe several problems that could be solved with a machine learning approach. Organizers of the course will make sure that only those problems are selected that are suitable for a machine learning approach and where sufficient amounts of data (and labels) are available. Students will organize themselves into small groups of 3-5 students, where each group works on solving a specific problem. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Every two weeks, each group will present ideas and progress during a short presentation followed by a discussion with all course members. At the end of the course, students will present their final results and submit source code. In addition, they will describe the developed method in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.

Note: The course AI4Good is not related to Hack4Good, which is a students’ initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/.

**Prerequisites / notice**
Students with a strong background in machine learning and excellent programming skills (preferably in Python)

#### 851-0467-00L  From Traffic Modeling to Smart Cities and Digital Democracies  W  3 credits  2S  D. Helbing, S. Mahajan

**Abstract**
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will reflect on the question of how democracy could be digitally upgraded to promote innovation, sustainability, and resilience.

**Objective**
To collect credit points, students will have to give a 30-40 minute presentation in the seminar, after which the presentation will be discussed. The presentation will be graded.

**Content**
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.
Further literature will be recommended in the lectures.
A Sampler of Histories and Philosophies of Mathematics

Particularly suitable for students D-CHAB, D-INFK, D-ITET, D-MATH, D-PHYS

This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students’ horizons to the plurality of mathematical cultures and practices

Contract Design I

This course is taught by Professor Alexander Stremitzer (https://laweconbusiness.ethz.ch/group/professor/stremitzer.html). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contact Design I, you will learn what the content of a contract should be so that parties can reach their goals.

You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2021)” and enroll. The password is “ContractDesign01”.

Number of participants limited to 160.
Max 80 ETHZ and 80 UZH Students

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvIdfG70zq0). However, this course prioritizes applications of contract design.

Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

This course is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderraherrera@uzh.ch).
Abstract
Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.

Objective
Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis. In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

Content
The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

- Empirical Research and Network Data
- Macro and Micro Structure
- Centrality
- Roles
- Cohesion

Lecture notes
Lecture notes are distributed via the associated course moodle.

Literature

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853-0061-00L Introduction to Cybersecurity Politics W 3 credits 2G M. Dunn Cavelty, F. J. Egloff

Abstract
The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures).

Objective
Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.

Content
We start with an overview of cybersecurity issue from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulatory contexts).

Lecture notes
A script with background information and comments on the literature will be made available at the beginning of the semester.

Lecture notes
Lecture notes are distributed via the associated course moodle.

Literature

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853-8002-00L The Role of Technology in National and International Security Policy W 3 credits 2G M. Haas, A. Dossi, M. Leese, O. Thranert

Abstract
The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective
Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content

Literature
- Cohesion
- Roles
- Macro and Micro Structure
- Centrality
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

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851-0650-00L AI4Good W 3 credits 2G J. D. Wegner

Abstract
The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members.

Objective
Given a specific problem in global development, students shall learn to self-responsibly design, implement and experimentally evaluate a suitable solution. Students will also learn to critically evaluate their ideas and solutions together with all course members in a broader context that go beyond mere technical solutions, but touch on ethics, local culture etc., too.
The course is focused on the investigation of scientific thought between 1000 and 1700, that is to say the period that saw the flourishing of natural philosophy and the birth of the modern scientific method. Several case-studies, taken from different scientific fields (especially physics, chemistry, and astronomy), will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Prerequisites / notice
Students with a strong background in machine learning and excellent programming skills (preferably in Python)

851-0175-00L Images of the Human

Abstract
This seminar will explore the multiple transformations of the conception of the "human" in the face of the current scientific, social and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences.

Objective
By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.

Content
The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the "human". In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre's activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

851-0742-01L Contract Design II

Abstract
This course is taught by Professor Alexander Stremitzer (https://lawecon.ethz.ch/group/professors/stremitzer.html).

To be considered for Contract Design II, you must have completed Contract Design I in the same semester.

Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

Objective
There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the content and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegocalberto.calderaherrera@uzh.ch).

Prerequisites / notice
To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

851-0125-65L A Sampler of Histories and Philosophies of Mathematics

Prerequisites / notice
Particularly suitable for students D-CHAB, D-INF, D-ITET, D-MATH, D-PHY.

Objective
The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various theoretical approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

851-0197-00L Medieval and Early Modern Science and Philosophy

Objective
The course is focused on the investigation of scientific thought between 1000 and 1700, that is to say the period that saw the flourishing of natural philosophy and the birth of the modern scientific method. Several case-studies, taken from different scientific fields (especially algebra, astronomy, and physics) are presented in class in order to examine the relation between science and philosophy and the shift from medieval times to the early modern world.

D-MATL

Number 851-0703-00L

Title Introduction to Law

Prerequisites / notice
Students who have attended or will attend the lecture "Introduction to Law for Civil Engineering and Architecture" (851-0703-03L) or "Introduction to Law" (851-0708-00L), cannot register for this course unit.

 Particularly suitable for students of D-ARCH, D-MAVT, D-MATL

Abstract
This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces aspects of competition law as treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

Prerequisites / notice
- The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver roos (oliver.roos@sipo.gess.ethz.ch).

701-0703-00L Environmental Ethics W 2 credits 2V A. Deplazes Zemp

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Content
- Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarisation with various basic standpoints within environmental ethics.
- Cross-section topics: sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

Lecture notes
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

Literature
- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neill et al., Environmental Values, 2008

Generel introductions:
- Marcus Düwell et. al (Hrsg.), Handbuch Ethik, 2. Auflage, Stuttgart (Metzler Verlag), 2006
- Johann S. Ach et. al (Hrsg.), Grundkurs Ethik 1. Grundlagen, Paderborn (mentis) 2008

Prerequisites / notice
The procedure for accumulating CP will be explained at the start of term.
The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors.

Objective
- Getting acquainted to the extended risk concept
- Evaluation of the risks caused by technology within the societal context
- Knowledge about the mode science and society handle current environmental risks (examples gene- and nanotechnology)
- Knowledge about handling risks (e.g. precautionary principle, protection goal, damage definition, ethics)

Content
- Risks and technical systems (risk categories, risk perception, risk management)
- Illustration with case studies (nanotechnology)
- Implementation (politics, science, media, etc.)
- Decision making (technology assessment, cost/benefit analysis etc.)
- The role of the media
- prospects for future developments

Lecture notes
Copies of slides and selected documents will be distributed.

Prerequisites / notice
The lecture is held biweekly (for 2 hours). The dates are 3.9.; 30.9. (instead of 7.10); 21.10; 4.11.; 18.11.; 2.12.; 16.12.

**853-0061-00L Introduction to Cybersecurity Politics**

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<th>Domain A - Subject-specific Competencies</th>
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<td>Domain B - Method-specific Competencies</td>
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<td>Problem-solving</td>
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<td>Domain D - Personal Competencies</td>
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<td>Self-direction and Self-management</td>
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The lecture is being supported by a website on Moodle.

Literature
The literature for each session will be available on Moodle.

**853-8002-00L The Role of Technology in National and International Security Policy**

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<thead>
<tr>
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The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver Roos, oliver.roos@ai4good.ethz.ch.

Literature
Literatur für die einzelnen Sitzungen wird auf Moodle bereitgestellt.

Prerequisites / notice
The lecture is supported by a website on Moodle.

**851-0650-00L AI4Good**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
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The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with all course members.

Objective
Given a specific problem in global development, students shall learn to self-responsibly design, implement and experimentally evaluate a suitable solution. Students will also learn to critically evaluate their ideas and solutions together with all course members in a broader context that go beyond mere technical solutions, but touch on ethics, local culture etc., too.
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Every two weeks, each group will present ideas and progress during a short presentation followed by a discussion with all course members. At the end of the course, students will present their final results and submit source code. In addition, they will describe the developed model in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.

Note: The course AI4Good is not related to Hack4Good, which is a students' initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/.

Prerequisites / notice
Students with a strong background in machine learning and excellent programming skills (preferably in Python)

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>851-0252-10L</td>
<td>Project in Behavioural Finance</td>
<td>W</td>
<td>3</td>
<td>6</td>
<td>S. Andraszewicz, C. Hölscher, A. C. Roberts</td>
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<td>Number of participants limited to 40</td>
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**Abstract**
In this seminar, students will study cognitive processes, behaviour and the underlying biological response to financial decisions. Research methods such as asset market experiments, lottery games, risk preference assessment, psychometrics, neuroimaging and psychophysiology of decision processes will be discussed. Financial bubbles and crashes will be the core interest.

**Objective**
This course has four main goals:
1) To learn about the most important topics within Behavioural Finance
2) To learn how to conduct behavioural studies, design experiments, plan data collection and experimental tasks
3) To learn about causes of market crashes, factors that influence them, traders' behaviour before, during and after financial crises
4) To investigate a topic of interest, related to behaviour of traders during market crashes.

Additionally, the course gives to the students the opportunity to practice oral presentations, communication skills, report writing and critical thinking.

**Content**
The course provides an overview of the most important topics in Behavioural Finance. First part of the course involves reading scientific articles, which will be discussed during the seminar. Therefore, attendance is required to pass the course. Each week, a student volunteer will present a paper and the presentation will be followed by a discussion. After obtaining sufficient knowledge of the field, students will select a topic for a behavioural study of their own. The final assignment consists of preparing and conducting a small behavioural study/experiment, analysing the data and presenting the project in the final meeting of the class. Each student will write a scientific report of their study.

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<tr>
<td>851-0738-00L</td>
<td>Intellectual Property: Introduction</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Schweizer</td>
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<td>Particularly suitable for students of D-CHAB, D-INFK, D-ITET, D-MAVT, D-MATL, D-MTEC</td>
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**Abstract**
The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles are developed based on current cases.

**Objective**
The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

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<th>Lecturers</th>
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<tr>
<td>363-0565-00L</td>
<td>Principles of Macroeconomics</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>J.-E. Sturm</td>
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<td></td>
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**Abstract**
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

**Objective**
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

**Lecture notes**
The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

**Literature**
The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2020), Economics, Cengage Learning, Fifth Edition. This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filippini).

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

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies

- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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363-0503-00L Principles of Microeconomics

W 3 credits 2G M. Filippini

**Abstract**
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

**Objective**
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

**Content**
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

**Lecture notes**
Lecture notes, exercises and reference material can be downloaded from Moodle.

**Literature**
N. Gregory Mankiw and Mark P. Taylor (2020), "Economics", 5th edition, South-Western Cengage Learning. The book can also be used for the course 'Principles of Microeconomics' (Sturm)

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Complementary:

**Prerequisites / notice**
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: not assessed

363-1109-00L Introduction to Microeconomics

- GESS (Science in Perspective):
  This course is only for students enrolled in a Bachelor's degree programme.

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

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

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

- Objective
  Students acquire a deeper understanding of basic microeconomic models.

  They acquire the ability to apply these models in the interpretation of real world economic contexts.

- Content
  Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

- Lecture notes
  Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

- Literature

363-1044-00L Applied Negotiation Seminar

- Abstract
  The block-seminar combines lectures introducing negotiation and negotiation engineering with the respective application through in-class negotiation case studies and games.
This course introduces students to legal, economic, and social perspectives on the increasing
law posed by the increasing rate of tech innovation and adoption generally and also by case-specific
economic and social importance of technology. We focus particularly on the challenges to current
traditional frameworks and to instigate changes in existing legal rules.

In particular,
- a series of brief lectures will introduce foundational aspects of negotiation science, such as rationality, fairness, and trust, as well as the
possible application of machine learning in negotiation
- three practitioners will describe lessons learnt in their negotiation domains (diplomacy, labor, and business) and allow time for Q&A and
discussion
- students will apply course input in a number of challenging simulations (ranging from simple 30 minute games to full-fledged international
ten party negotiations). In each game they will be asked to represent a party and negotiate as skillfully as they possibly can within the
constraints of their mandate
- each student will be assigned a scholarly paper (20 to 30 pages) between the two blocks to read. They will give a 20 minute group
presentation with one or two of their peers and submit a brief reflection report after the seminar

The course size is deliberately limited (30 maximum) to enable ample opportunity to interact with the lecturers, guests and each other.

<table>
<thead>
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<th>Contract Design I</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>A. Stremitzer</th>
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<tbody>
<tr>
<td>This course is taught by Professor Alexander Stremitzer (<a href="https://www.uzh.ch/professor/stremitzer.html">https://www.uzh.ch/professor/stremitzer.html</a>). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contract Design I, you will learn what the content of a contract should be so that parties can reach their goals. You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2021)” and enroll. The password is “ContractDesign01”.</td>
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</tbody>
</table>

Number of participants limited to 160.
Max 80 ETHZ and 80 UZH Students

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video
epresentations introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral
c Hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome
video at this link (https://www.youtube.com/watch?v=CvlfdG70zq0). However, this course prioritizes applications of contract design.
Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil &
gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types
of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class
time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post
questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload
them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. This is because UZH
students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Handouts, prerecorded videos, slides, and other materials

Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly
suitable for students of D-ARCH, D-BAUG, D-CHAB, DMATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract
Design I, please send an e-mail to Professor Stremitzer's Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

Number of participants limited to 30.

This course introduces students to legal, economic, and social perspectives on the increasing
economic and social importance of technology. We focus particularly on the challenges to current
law posed by the increasing rate of tech innovation and adoption generally and also by case-specific
features of prominent near-future technologies.

The course is intended for a wide range of engineering students, from machine learning to
bioengineering to human computer interaction, as well as for law students interested in acquiring a
better understanding of state-of-the-art technology.

The course will combine both an overview of major areas of law that affect the regulation of
technology and also guest lectures on the state-of-the art in a variety of important technologies,
ranging from autonomous vehicles to fair artificial intelligence to consumer-facing DNA technologies.

The course is open to ETH students through the Science in Perspective program of the Department
of Humanities, Social and Political Sciences.

Autumn Semester 2021
Page 1004 of 2152
The planned course outline is below

1. Overview of science, law, and technology
   a. Studies of law and technology
   b. Should science be regulated, and if so, how?
   c. Technology as a social problem

2. Designing technology for humans
   a. Attention fiduciaries and the digital environment
   b. Does technology weaponize known problems of bounded human rationality?
   c. Should technology be regulated as a psychotropic substance? An addictive substance?
   d. Can technology make life easier?
   e. Psychological effects of surveillance

3. Governing tech
   a. Can small governments regulate big tech?
   b. National and supranational legislation
   c. Enforcing the law with technology
   d. Can enforcement be baked into technology?

4. AI and fairness
   a. Discrimination
   b. Privacy
   c. Opacity
   d. AI and due process

5. Trade secret and technological litigation
   a. Trade secret is a long-standing tool for litigation but does it enjoy too much deference?
   b. Trade secrets and the rights of employees

6. Enforcement against tech
   a. Big tech and antitrust
   b. Consumer protection

7. The Digital Battlefield
   a. Technology for spying
   b. Spying on technology companies
   c. Race to be AI superpower
   d. Immigration policy

8. Contract law
   a. Smart contracts
   b. Modernizing contract law and practice
   c. Regulating cryptocurrencies

9. Tort law
   a. Applying existing tort law to new autonomous technologies
   b. Personhood and personal responsibility
   c. Victim entitlements

10. Self-driving cars and other autonomous robotics
    a. Legal regimes
    b. Diversity in morality judgements related to autonomous vehicles

11. Biometrics
    a. Widespread use of facial recognition
    b. Law enforcement
    c. Connecting biometrics to social data
    d. Solving crimes with biometrics

12. New Biology and Medicine
    a. Unregulated science (biohackers)
    b. Promising technology before it can be delivered
    c. Connecting medicine to social data
    d. Using technology to circumvent medical regulations

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851-0760-00L Building a Robot Judge: Data Science for Decision-Making

Particularly suitable for students of D-INFK, D-ITET, D-MTEC

W 3 credits 2V E. Ash

Abstract
This course explores the automation of decisions in the legal system. We delve into the machine learning tools needed to predict judge decision-making and ask whether techniques in model explanation and algorithmic fairness are sufficient to address the potential risks.

Objective
This course introduces students to the data science tools that may provide the first building blocks for a robot judge. While building a working robot judge might be far off in the future, some of the building blocks are already here, and we will put them to work.
The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe how data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, climate change exerts a pressure on us to significantly change our individual and collective behavior. Such a pressure raises questions about our ecological niche.

Students will investigate and implement the relevant machine learning tools for making legal predictions, including regression, classification, and deep neural networks models. We then use these predictions to better understand the operation of the legal system. In a semester project, student groups will conceive and implement a research design for examining this type of empirical research question.

### Content

Data science technologies have the potential to improve legal decisions by making them more efficient and consistent. On the other hand, there are serious risks that automated systems could replicate or amplify existing legal biases and rigidities. Given the stakes, these technologies force us to think carefully about notions of fairness and justice and how they should be applied.

The focus is on legal prediction problems. Given the evidence and briefs in this case, how will a judge probably decide? How likely is a criminal defendant to commit another crime? How much additional revenue will this new tax law collect? Students will investigate and implement the relevant machine learning tools for making these types of predictions, including regression, classification, and deep neural networks models.

We then use these predictions to better understand the operation of the legal system. Under what conditions do judges tend to make errors? Against which types of defendants do parole boards exhibit bias? Which jurisdictions have the most tax loopholes? Students will be introduced to emerging applied research in this vein. In a semester paper, students (individually or in groups) will conceive and implement an applied data-science research project.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0761-00L</td>
<td>Building a Robot Judge: Data Science for Decision-Making (Course Project)</td>
<td>2</td>
<td>W</td>
<td>E. Ash</td>
</tr>
<tr>
<td>851-0650-00L</td>
<td>AI4Good</td>
<td>3</td>
<td>W</td>
<td>J. D. Wegner</td>
</tr>
<tr>
<td>851-0742-01L</td>
<td>Contract Design II</td>
<td>1</td>
<td>W</td>
<td>A. Stremitzer</td>
</tr>
<tr>
<td>851-0101-80L</td>
<td>Basic Problems of Environmental Ethics</td>
<td>3</td>
<td>W</td>
<td>L. Wingert</td>
</tr>
</tbody>
</table>

Abstract

**851-0761-00L**

Building a Robot Judge: Data Science for Decision-Making (Course Project)

This is the optional course project for "Building a Robot Judge: Data Science for the Law."

Please register only if attending the lecture course or with consent of the instructor.

Some programming experience in Python is required, and some experience with text mining is highly recommended.

**851-0650-00L**

AI4Good

The AI4Good course is a hackathon turned into a full course. At the beginning, stakeholders active in the development sector will describe several problems that could be solved with a machine learning approach. Students will spend the semester on designing, implementing, and testing suitable solutions using machine learning. Progress will be discussed with solutions members.

Objective

In a semester paper, students (individually or in groups) will conceive and implement their own research project applying natural language tools to legal texts. Some programming experience in Python is required, and some experience with NLP is highly recommended.

**851-0742-01L**

Contract Design II

This course is taught by Professor Alexander Stremitzer (https://lawecon.ethz.ch/group/professors/stremitzer.html). To be considered for Contract Design II, you must have completed Contract Design I in the same semester. Students can only register for Contract Design II after having obtained approval by Prof. Stremitzer.

Objective

Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract.

Prerequisites / notice

Students with a strong background in machine learning and excellent programming skills (preferably in Python) are preferred.

**851-0101-80L**

Basic Problems of Environmental Ethics

Climate change exerts a pressure on us to significantly change our individual and collective behavior. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?

Objective

Participants should become familiar with basic approaches to central problems in environmental ethics.

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

In recent years, knowledge about intellectual property has become increasingly important for engineers and scientists. Both in production and future professional life, engineers and scientists will have to deal with intellectual property questions, for example when they publish their research, when they start a company, or when they use industrial standard definitions of technical inventions and the use of patent information.

The lecture gives an overview of the fundamental aspects of intellectual property, which plays an important role in the daily routine of engineers and scientists. The lecture aims to make participants aware of the various methods of protection and to put them in a position to use this knowledge in the workplace.

Case studies will illustrate and deepen the topics addressed during the lecture. The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

The seminar will include practical exercises on how to use and search patent information. Basic knowledge of how to read and evaluate patent documents as well as how to use publicly available patent databases to obtain the required patent information will also be provided.

- Patents as a source of technical and business information
- Practical aspects of intellectual property in day-to-day research, at the workplace and for the formation of start-ups.

The lecture addresses students in the fields of engineering, science and other related technical fields.

The course provides an introduction to Swiss and European intellectual property law (trademarks, copyright, patent and design rights). Aspects of competition law are treated insofar as they are relevant for the protection of intellectual creations and source designations. The legal principles developed are based on current cases.

The aim of this course is to enable students at ETH Zurich to recognize which rights may protect their creations, and which rights may be infringed as a result of their activities. Students should learn to assess the risks and opportunities of intellectual property rights in the development and marketing of new products. To put them in this position, they need to know the prerequisites and scope of protection afforded by the various intellectual property rights as well as the practical difficulties involved in the enforcement of intellectual property rights. This knowledge is imparted based on current rulings and cases.

Another goal is to enable the students to participate in the current debate over the goals and desirability of protecting intellectual creations, particularly in the areas of copyright (keywords: fair use, Creative Commons, Copyleft) and patent law (software patents, patent trolls, patent thickets).

**851-0735-10L**  **Business Law**  
Number of participants limited to 100

**Objective**
The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall be familiar with the issues of corporate compliance, i.e. the system to ascertain that all legal and ethical rules are observed.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

**Lecture notes**
A comprehensive script will be made available online on the moodle platform.

**853-0047-01L**  **World Politics Since 1945: The History of International Relations (Without Exercises)**

Students who have attended or will attend the lecture "Introduction to Law for Civil Engineering and Architecture (851-0708-00L)" or "Introduction to Law" (851-0708-00L), cannot register for this course unit.

**Objective**
By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of World War II. The first part of the series deals with the development of and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

**Content**
Basic concepts of law, sources of law.
Private law: Contract law (particularly contract for work and services), tort law, property law.
Public law: Human rights, administrative law, procurement law, procedural law.

**Lecture notes**
Further documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15142).

**853-0725-00L**  **History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)**

A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series asks whether one single model of modernization prevailed on the 'Old Continent' or whether we need to differentiate regionally. A special focus lies on the Swiss experience.
Getting acquainted with the extended risk concept

The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors.

Power Point Slides and references will be made available in digital form during the course of the semester.

This lecture series does not build upon specific previous knowledge by the students.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>Credits</th>
<th>V</th>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>701-0703-00L</td>
<td>Environmental Ethics</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Deplazes Zemp</td>
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<tr>
<td>701-0985-00L</td>
<td>Social Intercourse with Current Environmental Risks</td>
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<td>1</td>
<td>1V</td>
<td>B. Nowack</td>
</tr>
<tr>
<td>853-0061-00L</td>
<td>Introduction to Cybersecurity Politics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Dunn Cavelty, F. J. Eglolf</td>
</tr>
</tbody>
</table>

Objective

At the end of this lecture course, students can: (a) highlight the most important changes in the "long nineteenth century" in Europe (b) explain their long-term effects; and (c) relate these changes to global developments today.

Content

The thematic foci include: Industrialization on the British Isles, urban growth in Switzerland, the difficult road to democracy in Germany, and French individualism.

Lecture notes

Power Point Slides and references will be made available in digital form during the course of the semester.

Literature

Mandatory and further reading will be listed on the course plan that is made available as from the first session.

Prerequisites / notice

This lecture series does not build upon specific previous knowledge by the students.

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<thead>
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<td>Introduction to Cybersecurity Politics</td>
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Domain A - Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork
- Sensitivity to Diversity

Domain D - Personal Competencies

- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Objective
Participants will gain a deep overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content

Literatur für die einzelnen Sitzungen wird auf Moodle bereitgestellt.

The Role of Technology in National and International Security Policy

Prerequisites / notice
The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver Roos, oliver.roos@alapo.gess.ethz.ch.

Contract Design II

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Objective
There is a possibility that representatives from companies that were previously engaged in similar deals will visit us in class and tell you about their experience firsthand. In Contract Design I, you will receive more detailed information on the contract and learning objectives of Contract Design II. If you have urgent questions, please do not hesitate to send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

Prerequisites / notice
To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

D-PHYS

Complex Social Systems: Modeling Agents, Learning, and Games

Prerequisites: Basic programming skills, elementary probability and statistics.

Abstract
This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.

Objective
The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically.

Content
Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a developed method in form of a scientific paper of 8 pages. Grading will depend on the source code, the paper, and active participation in class.

Contract Design II

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Agents-Based Modeling
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization

Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

Further literature will be recommended in the lectures.

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

**581-0650-00L**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught competencies</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competences</td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Domain C - Social Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
</tr>
<tr>
<td>Negotiation</td>
<td>not assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Domain D - Personal Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
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851-0175-00L

<table>
<thead>
<tr>
<th>Subject</th>
<th>Images of the Human</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>J. L. Gastaldi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This seminar will explore the multiple transformations of the conception of the “human” in the face of the current scientific, social and technological challenges, focusing on those related to recent digital technologies and practices. The lectures will be delivered by researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences.</td>
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<tr>
<td>Objective</td>
<td>By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to current trends in science, technology and society, particularly in the context of new digital practices.</td>
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<tr>
<td>Content</td>
<td>The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the “human”. In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre's lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre’s activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.</td>
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</table>

Note: The course AI4Good is not related to Hack4Good, which is a students’ initiative organized by the Analytics Club at ETH. For more information about Hack4Good check out the website: https://analytics-club.org/wordpress/hack4good/.

Students with a strong background in machine learning and excellent programming skills (preferably in Python)
851-0125-65L A Sampler of Histories and Philosophies of Mathematics

Title: A Sampler of Histories and Philosophies of Mathematics
Type: W
ECTS: 3 credits
Hours: 2V
Lecturers: R. Wagner

Abstract: This course will review several case studies from the ancient, medieval and modern history of mathematics. The case studies will be analyzed from various philosophical perspectives, while situating them in their historical and cultural contexts.

Objective: The course aims are:
1. To introduce students to the historicity of mathematics
2. To make sense of mathematical practices that appear unreasonable from a contemporary point of view
3. To develop critical reflection concerning the nature of mathematical objects
4. To introduce various methodological approaches to the philosophy and history of mathematics
5. To open the students' horizons to the plurality of mathematical cultures and practices

851-0197-00L Medieval and Early Modern Science and Philosophy

Title: Medieval and Early Modern Science and Philosophy
Type: W
ECTS: 3 credits
Hours: 2V
Lecturers: E. Sammarchi

Abstract: The course analyses the evolution of the relation between science and philosophy during the Middle Age and the Early Modern Period.

Objective: The course aims are:
- to introduce students to the philosophical dimension of science
- to develop a critical understanding of scientific notions
- to acquire skills in order to read and comment on scientific texts written in the past ages.

Content: The course is focused on the investigation of scientific thought between 1000 and 1700, that is to say the period that saw the flourishing of natural philosophy and the birth of the modern scientific method. Several case-studies, taken from different scientific fields (especially algebra, astronomy, and physics) are presented in class in order to examine the relation between science and philosophy and the shift from medieval times to the early modern world.

851-0742-01L Contract Design II

Title: Contract Design II
Type: W
ECTS: 1 credit
Hours: 1U
Lecturers: A. Stremitzer

Abstract: Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract.

Objective: Contract Design II is a masterclass in the form of an interactive clinic that allows you to deepen your understanding of contracting by applying insights from Contract Design I to a comprehensive case study. Together with your classmates, you are going to advise a (hypothetical) client organization planning to enter a complex transaction on how to structure the underlying contract.

Prerequisites / notice: To enable you to work under the close supervision of your professor and his team, only a small group of students with backgrounds in law, business, or engineering is admitted to this course. This simulation is time-consuming and challenging. Hence, we can only admit the most successful and motivated students to this class. Further information on the application process will follow.

The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

To facilitate your planning, the course is organized in terms of weekly units.

### 851-0707-00L Space Planning Law and Environment

**Abstract**
System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

**Objective**
Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

**Content**

**Lecture notes**
Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999

### 701-0703-00L Environmental Ethics

**Abstract**
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

**Objective**
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

**Content**
- Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarisation with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

**Lecture notes**
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

**Literature**
- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neill et al., Environmental Values, 2008
- Konrad Ott/Jan Dierks/Lieske Voget-Kleschin, Handbuch Umwelthethik, 2016

**Prerequisites / notice**
The procedure for accumulating CP will be explained at the start of term.

### 701-0747-00L Environmental Policy of Switzerland

**Abstract**
This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

**Objective**
Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

**Content**
The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

**Lecture notes**
The reader and additional lecture material and exercises will be posted on Moodle.

**Literature**
Reader and additional lecture material on moodle.

**Prerequisites / notice**
The detailed semester program (syllabus) is made available to the students at the beginning of the semester.

During the lecture we will work with Moodle and eduApp. We ask that all students register themselves on these platforms before the lecture and to bring a laptop, tablet or smartphone to class, so that you can complete exercises using Moodle and eduApp.

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### 851-0650-00L AI4Good

**Objective**
- Getting acquainted with the extended risk concept
- Evaluation of the risks caused by technology within the societal context
- Knowledge about the mode science and society handle current environmental risks (examples gene- and nanotechnology)
- Knowledge about handling risks (e.g. precautionary principle, protection goal, damage definition, ethics)

**Content**
- Risks and technical systems (risk categories, risk perception, risk management)
- Illustration with case studies (nanotechnology)
- Implementation (politics, science, media, etc.)
- Decision making (technology assessment, cost/benefit analysis etc.)
- The role of the media
- Prospects for future developments

**Lecture notes**
Copies of slides and selected documents will be distributed

**Prerequisites / notice**
The lecture is held biweekly (for 2 hours). The dates are 3.9.; 30.9. (instead of 7.10); 21.10; 4.11.; 18.11.; 2.12.; 16.12.

**851-0175-00L Images of the Human**

**Objective**
By the end of the course, students will be able to describe and compare different conceptions of the human at work in multiple fields of the humanities and the social sciences. They will be able to evaluate both the differences and the convergences between those conceptions, and critically assess their relation to science, technology and society.

**Content**
- The remarkable development of AI in the past decade has brought about a renewed urge to rethink our image of the “human.” In this way, computer science and technology join other scientific disciplines having experienced the same need in the face of current challenges, such as climate change or the global pandemic, which question the place of the human in its environment. Such circumstances reveal that a science of the human is today more necessary than ever. For this reason, the Turing Centre’s lecture series of this year will be dedicated to exploring the multiple images of the human at work across the human sciences and their transformation as a consequence of the current global challenges. In line with the Turing Centre’s activities, the focus will be on challenges related to recent digital technologies and practices. Various researchers from ETH and abroad, with different disciplinary backgrounds in the humanities and the social sciences, will present what they consider crucial concepts, methods, challenges, and limits in our investigations about the human and its relation to machines, animals and nature.

**Prerequisites / notice**
Students with a strong background in machine learning and excellent programming skills (preferably in Python)

### 851-0421-00L Sapiens: A Reading Course

**Objective**

- The aim of the seminar is to introduce students to the history of science in anthropology, prehistory and popular science literature on the history of mankind by reading “Sapiens”. In addition to studying and critically discussing the original text, the students explore significant scientific and historical contexts of the book in small groups and present them in the seminar. In this way, they develop an understanding of the underlying narratives and popular science genres that inform “Sapiens”.

### 851-0724-01L Real Estate Property Law

**Objective**
- Overview of the legal norms of land registry and surveying law.

**Content**
- Basic principles of material and formal land registry law, components of the land register, consequences of the land register, the registration process, legal principles of surveying, the reform of official surveying, liability of the geom-eter.
## Lecture notes

Abgegebene Unterlagen: Skript in digitaler Form

Pflichtlektüre: Meinrad Huser, Schweizerisches Vermessungsrecht, unter besonderer Berücksichtigung des Geoinformationsrechts und des Grundbuchrechts, Beiträge aus dem Institut für schweizerisches und internationales Baurecht der Universität Freiburg/Schweiz, Zürich 2014

### Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories assessed
- Techniques and Technologies assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Project Management not assessed

**Domain C - Social Competencies**

- Communication not assessed
- Cooperation and Teamwork assessed
- Customer Orientation assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity assessed

**Domain D - Personal Competencies**

- Negotiation assessed
- Adaptability and Flexibility not assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management not assessed

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### 851-0101-80L Basic Problems of Environmental Ethics

**W** 3 credits 2G L. Wingert

**Abstract**

Climate change exerts a pressure on us to significantly change our individual and collective behaviour. Such a pressure raises questions like: Who has to give up what? What is a fair distribution of the burdens in the struggle against the climate change? What is the reasonable understanding of our relation to nature? How should we run our economies?

**Objective**

Participants should become familiar with basic approaches to central problems in environmental ethics.

The course will try to give an argument-based answer to the question: What are the responsibilities for individuals (e.g. as consumers), and for collectivities (e.g. states and firms).

Another focus will be to clarify the concept of "climate justice".

The course should also enable participants to evaluate different answers to the question how we should organize our economies for securing our ecological niche.

**Literature**


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### Language Courses of the UZH and ETH Zurich

**Language Courses of the UZH and ETH Zurich**

A maximum of three credits from language courses may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.

**Course fees:** [https://www.sprachenzentrum.uzh.ch/en/angebot/Kursgebuehren.html](https://www.sprachenzentrum.uzh.ch/en/angebot/Kursgebuehren.html)

**Registration dates:** [https://www.sprachenzentrum.uzh.ch/en/angebot.html](https://www.sprachenzentrum.uzh.ch/en/angebot.html)

**Number** 851-0816-07L

**Title** French B2-C1: Language and Literature

**Number** 851-0816-07L

**Type** W

**ECTS** 2 credits

**Hours** 1G

**Lecturers** University lecturers

**Abstract**

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zurich".

**Course fees:** [https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html](https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html)

**Registration dates:** [https://www.sprachenzentrum.uzh.ch/en/angebot.html](https://www.sprachenzentrum.uzh.ch/en/angebot.html)

**Objective**

This course offers participants the opportunity to read short stories in order to raise their awareness of linguistic aspects and cultural issues in the Francophone world, and to improve their oral skills, mainly through oral presentations.

The primary objective of this course is to develop participants’ written comprehension and, more specifically, to refine their perception of the implicit meanings and cultural aspects present in the literary texts proposed for reading. The course further aims to raise participants’ awareness of contemporary cultural issues in the Francophone world. Another goal is to improve participants’ oral skills, specifically so they can deliver structured presentations and express personal, informed, and nuanced opinions.
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<th>Instructor Type</th>
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<tbody>
<tr>
<td>851-0815-04L</td>
<td>French B2: Brush Up Your Skills</td>
<td>W 2</td>
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<td>University lecturers</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<td>The course is organized around the communicative tasks that participants learn to perform. These relate to the university environment and are addressed both in terms of essential language skills at B2 level and of extra-linguistic skills (cultural knowledge, gestures, etc.) required to deal with these situations.</td>
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<td>The objective of this course is to familiarize participants with the performance of communicative tasks specific to the academic world and, in so doing, to consolidate their general production and comprehension skills (oral and written) at B2 level.</td>
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<td>851-0815-15L</td>
<td>French B2: Debating and Presentation Skills</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<td>This course offers participants the opportunity to initiate and practice debating in French by developing and improving specific linguistic tools in order to allow them to speak fluently in controversial discussions.</td>
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<td>This course allows participants to develop their speaking skills through active contributions in debates. More specifically, it aims at participants' production of clear and reasoned statements to ensure better communication. An additional goal is to improve participants' listening comprehension skills.</td>
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<td>851-0815-08L</td>
<td>French B2-C1: Debating and Presentation Skills</td>
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<td>University lecturers</td>
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<td>Based on the main controversial issues of the moment, this course offers participants the opportunity to reflect on the rhetorical tools essential to the art of debate and to put these tools into practice in order to improve their ability to express themselves quickly, effectively, and fluently.</td>
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<td>This course allows participants to develop specific skills in oral expression, as well as comprehension, in the context of controversial discussion. After observing various practices and rhetorical tools in the art of debate in an initial phase, participants put the theory into practice in order to produce clearly structured argumentation and improve their ability to interact effectively rhetorically and quickly in a controversial debate.</td>
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<td>851-0815-05L</td>
<td>French B2-C1: Textual Grammar</td>
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<td>University lecturers</td>
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<td>This course offers participants the opportunity to recognize, practice, and improve some of the fundamental and relevant linguistic tools they need in order to write academic texts in French.</td>
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<td>The main objective of this course is to improve participants' competence in written French through the mastery of grammatical rules and their practical application; this will ensure the correctness of participants' utterances at text level and help them with some difficult areas of the French language. The course focuses on a descriptive approach of linguistic tools to improve written academic French (reports, abstracts) and business writing in general (covering letters) through targeted exercises.</td>
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<td>851-0826-06L</td>
<td>Italian B2-C1: Outside the Classroom</td>
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<td>Does not take place this semester.</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<td>This course allows participants to practice Italian in a real-life situation: At the Zurich art museum (Kunsthaus), participants look at art works while listening to an Italian audio guide; they then discuss the art. The course alternates between seven museum visits and seven in-class lessons. At home, participants study their chosen art works in more depth and prepare oral and written summaries.</td>
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<td>851-0828-03L</td>
<td>Italian B2-C1: Language Structure</td>
<td>Participants improve their understanding of grammatical usage by investigating written and spoken texts. They put newly acquired</td>
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<td>This course is designed for Bachelor's and Master's students from all disciplines who wish to improve their English from C1 towards C2</td>
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<td>The course gives participants the opportunity to broaden and intensify their knowledge of complex morphosyntactic structures. The</td>
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<td>objective is to improve their proficiency in expressing complex content. The aim is that at the end of the course, participants</td>
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<td>understand a wide range of texts and are able to express themselves clearly and effectively in a wide variety of oral and written</td>
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<td>situations. Using a range of written and oral activities, participants also practice aspects of grammar that often pose difficulties at an advanced level: verb tenses and modes, use of articles and pronouns, adjectives and past participle agreement, choice of prepositions, and word order. At the same time, the course focuses on vocabulary expansion.</td>
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<td>851-0823-00L</td>
<td>English Language and Literature (C1-C2)</td>
<td>Participants are able to write clear and detailed texts on scientific issues from their specific fields of study. Further activities enable participants to enhance vocabulary and grammar learning. Participants receive written feedback on their written work, and recurring errors are discussed in class.</td>
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<td>This course is designed for Bachelor and master students at C1-C2 level. The course enhances students' appreciation and understanding of literature in English. Through the analysis and interpretation of literary texts, students improve their analytical and English language skills; their grammar skills through writing; and their range of vocabulary through reading, discussions, and writing.</td>
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<td>The aims of the course are to: * Introduce students to a variety of literary texts in English * Help students to develop critical, creative, and personal approaches to analyzing literary texts and by extension become more astute readers in general * Provide students with an opportunity to enhance and practice their argumentation skills in discussions and in writing * Improve the ways in which students organize their ideas and arguments in a sustained, coherent, and logical manner * Improve students grammatical and lexical repertoire through reading and discussion * Impart a life-long interest in literature written in English</td>
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<td>851-0832-10L</td>
<td>Advanced English for Academic Purposes (C1-C2)</td>
<td>Participants should already have reached C1 level (advanced) as defined in the Common European Framework of Reference for Languages (CEFR). The course is also open to participants whose level is above C1. The course aims to train and develop linguistic skills at mastery level, with a focus on formal and informal academic lexis, on listening and oral communication skills, and on increasing fluency, accuracy, and complexity of spoken language. Students will work on writing well-structured descriptive texts and argumentative essays, with the aim of fulfilling the language requirements for study at an English-speaking university or following university Master's courses held in English.</td>
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<td>This course is designed for Bachelor’s and Master’s students from all disciplines who wish to improve their English from C1 towards C2 level and train their language skills at mastery level. Selected academic English features are included to add value to the course to meet standard entrance requirements by leading universities and colleges worldwide. Participants should already have reached C1 level (advanced) as defined in the Common European Framework of Reference for Languages (CEFR). The course is also open to participants whose level is above C1. The course aims to train and develop linguistic skills at mastery level, with a focus on formal and informal academic lexis, on listening and oral communication skills, and on increasing fluency, accuracy, and complexity of spoken language. Students will work on writing well-structured descriptive texts and argumentative essays, with the aim of fulfilling the language requirements for study at an English-speaking university or following university Master's courses held in English.</td>
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<td>851-0846-01L</td>
<td>Spanish B2: Starter</td>
<td>Participants improve their understanding of grammatical usage by investigating written and spoken texts. They put newly acquired</td>
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<td>language patterns into practice when writing and speaking, and they acquire vocabulary on current contemporary issues; they also acquire specialist vocabulary from their fields of study. Participants are able to write clear and detailed texts on scientific issues from their specific fields of study.</td>
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<td>851-0846-03L</td>
<td>Spanish B2: Grammar and Communication</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<td>Course fees: <a href="https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html">https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kursegebuehren1.html</a></td>
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<td></td>
<td>Abstract</td>
<td>The most important grammar topics of this course are past tense forms, subordinate clauses, linking devices, reported speech, periphrastic verb constructions, and verbs that express change. The course also deals with topics that typically cause problems for higher level learners, including ser/estar, por/para, and indicative and subjunctive forms of verbs.</td>
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<td></td>
<td>Objective</td>
<td>In this course, participants improve their comprehension of written and oral texts that deal with current issues, as well as of scientific texts from participants’ own fields of study. They are able to analyse various points of view and can create clear and detailed oral and written texts on scientific issues from their field of study, while taking a position and expressing definite views on these issues.</td>
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<tr>
<td>851-0849-00L</td>
<td>Brazilian Portuguese A1</td>
<td>W</td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>This course is designed for participants with no previous knowledge of Portuguese. In the course, participants learn simple basic vocabulary, common daily idiomatic expressions, and fundamental grammar. The focus is on the phonetic features of Portuguese language. Intercultural and cultural issues relating to Brazil are also taken into consideration.</td>
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<td></td>
<td>Objective</td>
<td>Participants can understand and form simple questions, messages, and requests.</td>
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<tr>
<td>851-0849-01L</td>
<td>Brazilian Portuguese A2</td>
<td>W</td>
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<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<td></td>
<td>Abstract</td>
<td>This course is designed for participants with a basic knowledge of Portuguese (level A1). The course deals with everyday topics. Participants practice simple forms of communication as these occur in daily life. Lexical and linguistic structures are taught within these contexts. Intercultural and socio-cultural issues relating to Brazil are also taken into consideration.</td>
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<td></td>
<td>Objective</td>
<td>Participants can talk and write about themselves and everyday topics using simple sentences. They can take part in simple daily conversations, understand and write simple messages, describe an event in a time sequence, and express wishes, assumptions, and recommendations.</td>
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<tr>
<td>851-0849-02L</td>
<td>Brazilian Portuguese B1</td>
<td>W</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>This course is designed for participants with an A2 level in Portuguese. The course deals with everyday topics. Participants practice forms of communication as these occur in daily life. Lexical and linguistic structures are taught within these contexts. Intercultural and socio-cultural issues relating to Brazil are also taken into consideration.</td>
<td></td>
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<td></td>
<td>Objective</td>
<td>Participants can deal with everyday situations; they can talk about their experiences, opinions, wishes, and plans in simple coherent sentences.</td>
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<tr>
<td>851-0885-09L</td>
<td>Modern Greek Language I A1.1</td>
<td>W</td>
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<td>No enrolment to this course at ETH Zurich. Book the corresponding course directly at &quot;Language Center of UZH and ETH Zürich&quot;.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>Modern Greek I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a four-semester Modern Greek course. The goal of the course is for participants to acquire basic language skills in speaking, listening comprehension, and reading and writing Greek script. The focus is also on building basic vocabulary and on acquiring basic grammar.</td>
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<td>Subject Code</td>
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<tr>
<td>851-0889-00L</td>
<td>Swedish I A1.2</td>
<td>2</td>
<td>W</td>
<td>Participants are able to use Swedish adequately in selected areas. They improve their listening comprehension skills and expand their vocabulary. They can read a simple text fluently and can answer content questions in speech and in writing. The focus is on speaking, reading, and writing.</td>
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<tr>
<td>851-0889-02L</td>
<td>Swedish II A2.1</td>
<td>2</td>
<td>W</td>
<td>Participants are able to use Swedish adequately in selected areas. They are able to use Swedish in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.2 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Describing an apartment, people, and objects; making comparisons; talking about past experiences and future plans; participating in interviews; asking for permission; giving advice; making appointments; and acting out dialogues.</td>
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<tr>
<td>851-0851-00L</td>
<td>Russian I A1.1</td>
<td>2</td>
<td>W</td>
<td>Participants are able to use Modern Greek adequately in selected areas. They have basic vocabulary skills, which they can use actively. They can read and write Greek script well. They can filter out a general overview from the information presented on Greek websites. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.1 level of the Common European Framework of Reference for Languages, and on the development of cultural competence. Special importance is attached to an academic environment and student life. Content areas that are embedded in various communicative tasks include: Giving information about yourself, your job, your studies, your place of residence, and your personal preferences; and conducting simple, everyday conversations (including ordering food and drink, shopping, and inquiring about places).</td>
</tr>
</tbody>
</table>
Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A1.1 level of the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Reading and writing Russian script; saying hello and goodbye; introducing yourself; asking for someone’s name; addressing someone; apologizing; indicating your country and place of origin and residence; stating your profession; talking about family; talking about your wellbeing; asking about prices; and ordering items in a café.

851-0853-00L Russian III A2.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A2.1 level on the Common European Framework of Reference for Languages. The course is the third part of a five-semester Russian course. In this course, participants extend their ability to express themselves, in particular regarding daily life (eating, shopping) and work and education (daily routines); it also extends participants’ grammar skills.

Abstract
Russian III leads to A2.1 level on the Common European Framework of Reference for Languages. The course is the third part (A2.1 level) of a four-semester Arabic course. The practice exercises relate to simple discursive situations in daily life. In terms of grammar, special importance is attached to systematically learning the Arabic verbal system.

851-0855-00L Russian V A2.2+

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use Russian adequately in selected areas. The focus is on speaking, reading comprehension, and listening comprehension skills at A2.1 level on the Common European Framework of Reference for Languages, and on developing cultural competence. Special importance is attached to an academic environment and student life. The course deals with the following content: Talking about food and meals; indicating packaging and quantities; talking about things you need or that you have to buy; talking to people while shopping; naming food establishments, crockery, and cutlery; extending invitations and responding to invitations; asking for explanations of unfamiliar terms; expressing congratulations and wishes; describing daily routines; describing actions in the present, past, and future; and explaining how you get to work.

Abstract
Russian V leads to A2.2+ level on the Common European Framework of Reference for Languages. The course is the final part of a five-semester Russian course. In this course, participants extend their ability to express themselves, in particular regarding daily life (holidays) and personality (biography, education, and professional career); it also extends participants’ grammar skills.

851-0861-01L Arabic I A1.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Objective
Participants are able to use Arabic language adequately in selected areas. The focus is on speaking; reading and listening comprehension at A1.1 level on the Common European Framework of Reference for Languages; learning Arabic script; and the development of cultural competence. The following content areas are embedded in various communicative tasks: Greeting each other, comparisons; talking about learning; indicating date and year; saying what you are interested in and what you are doing; giving biographical details; saying what you would like to do; making and obtaining recommendations; passing on information.

Abstract
Arabic I leads to A1.1 level on the Common European Framework of Reference for Languages. Arabic I is the first part (A1.1 level) of a four-semester Arabic course. The goal of the course is for participants to acquire basic language skills in speaking, listening comprehension, and the reading and writing of Arabic script.

851-0863-00L Arabic III A2.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Abstract
Arabic III leads to A2.1 level on the Common European Framework of Reference for Languages. Arabic III is the third part (A2.1 level) of a four-semester Arabic course. The practice exercises relate to simple discursive situations in daily life. In terms of grammar, special importance is attached to systematically learning the Arabic verbal system.
Objective

Participants are able to use the Arabic language adequately in selected areas and can conduct themselves in a culturally appropriate manner. To this end, the following content is dealt with: Talking about your life; daily routines; expressing wishes, commands, and eventualities; and talking about language and language learning (meta-language skills). Culturally, the focus is on useful phrases and appropriate conduct on important occasions such as holidays, weddings, births, and deaths. In terms of grammar, this course attaches particular importance to the systematization of the Arabic verbal system.

851-0875-00L

Chinese I A1.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurse/gebuehren.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/angebot.html

Abstract

Chinese I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a four-semester Chinese course. The goal of the course is to introduce participants to standard modern Chinese and to Chinese script, with a focus on speaking skills. The main focus is on communicating in everyday situations. Participants are able to use the Chinese language adequately in selected areas and can conduct themselves in a culturally appropriate manner. The focus is on oral language skills at A1.1 level of the Common European Framework of Reference for Languages. Special importance is attached to an academic environment and student life. After one semester, participants have basic knowledge of the structure of the script and of about 200 characters. Content areas that are embedded in various communicative tasks include:

- Greetings and farewells
- Presenting yourself and family members and giving information such as name, age, profession, origin, and telephone number
- Describing objects and institutions
- Language skills
- Shopping

Objective

Participants are able to use the Arabic language adequately in selected areas and can conduct themselves in a culturally appropriate manner. To this end, the following content is dealt with: Talking about your life; daily routines; expressing wishes, commands, and eventualities; and talking about language and language learning (meta-language skills). Culturally, the focus is on useful phrases and appropriate conduct on important occasions such as holidays, weddings, births, and deaths. In terms of grammar, this course attaches particular importance to the systematization of the Arabic verbal system.

851-0877-00L

Chinese III A2.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurse/gebuehren.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/angebot.html

Abstract

Chinese III leads to A2.1 level on the Common European Framework of Reference for Languages. It provides an extension of participants’ skills in standard modern Chinese and in Chinese script. The goal of the course is for participants to communicate in and deal with more complex everyday situations. Special importance is attached to an academic environment and student life.

Objective

Participants are able to use the Chinese language adequately in selected areas and can conduct themselves in a culturally appropriate manner. The focus is on oral language skills at A2.1 level of the Common European Framework of Reference for Languages; reading and writing skills are fostered simultaneously. Special importance is attached to an academic environment and student life. Participants learn about 200 new characters. (After three semesters, participants know about 600 characters). Content areas that are embedded in various communicative tasks include: Directions, your living situation, public transport, visits to doctors and hospitails, hairdresser appointments.

851-0881-00L

Japanese I A1.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurse/gebuehren.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/angebot.html

Abstract

Japanese I leads to A1.1 level on the Common European Framework of Reference for Languages. It is the first part of a five-semester Japanese course. The goal of the course is for participants to learn the basic vocabulary and sentence structures needed to communicate in everyday situations. This includes an introduction to Hiragana and Katakana syllabic writing and its use in word processing.

Objective

Participants are able to use the Japanese language adequately in selected areas. The focus is equally on fostering speaking, listening, writing, and reading skills at A1.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. Special importance is attached to an academic environment and student life. In addition, the two syllabic writing systems and the use of Japanese computer word processing are learnt. Content areas that are embedded in various communicative tasks include: Greetings, introducing yourself, and talking about yourself (personal and professional identity, studies, interests, daily life); asking for information; and requesting services.

851-0881-02L

Japanese 1 (A1.1)

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurse/gebuehren.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/angebot.html

Abstract

Elementary introduction to the Japanese language. Students acquire a basic vocabulary together with the most frequently used sentence structures, as well as the Hiragana and Katakana syllabaries. Reading and writing training includes use of the computer for Japanese text editing.

Objective

Everyday conversation / Reading simple texts written with Hiragana and Katakana syllabaries / Writing simple texts about everyday topics using the Hiragana and Katakana syllabaries on the computer.

851-0883-00L

Japanese III A2.1

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich.

Course fees: https://www.sprachenzentrum.uzh.ch/en/Sprachkurse/Kurse/gebuehren.html

Registration dates: https://www.sprachenzentrum.uzh.ch/en/angebot.html

Abstract

Participants are able to use the Japanese language adequately in selected areas. The focus is equally on fostering speaking, listening, writing, and reading skills at A2.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. Special importance is attached to an academic environment and student life. In addition, the two syllabic writing systems and the use of Japanese computer word processing are learnt. Content areas that are embedded in various communicative tasks include: Greetings, introducing yourself, and talking about yourself (personal and professional identity, studies, interests, daily life); asking for information; and requesting services.

Objective

Everyday conversation / Reading simple texts written with Hiragana and Katakana syllabaries / Writing simple texts about everyday topics using the Hiragana and Katakana syllabaries on the computer.
Participants are able to communicate orally in specific situations and read everyday texts in Sino-Japanese mixed script. The focus is on Japanese language adequately in selected areas. The focus is equally on fostering speaking, listening, writing, and reading skills at A1.2/A2.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. Grammar skills are also reviewed and extended. Participants learn about 60 new Kanji, thus improving their reading skills. The following content from daily interactions is dealt with: Various daily activities (logical sequences, expressing regrettable and gratifying events), distinguishing between, and using, deferential and informal language.

**Objective**

Participants are able to use the Japanese language adequately in selected areas. The focus is equally on fostering speaking, listening, writing, and reading skills at A1.2/A2.1 level of the Common European Framework of Reference for Languages, as well as on the development of cultural competence. Grammar skills are also reviewed and extended. Participants learn about 60 new Kanji, thus improving their reading skills. The following content from daily interactions is dealt with: Various daily activities (logical sequences, expressing regrettable and gratifying events), distinguishing between, and using, deferential and informal language.

**Prerequisites / notice**

Der Kurs richtet sich an Teilnehmende mit Lateinkenntnissen (Matura, Latinum).

**Prerequisites**


**Lecture notes**

Students mostly prepare the texts at home for class discussion. Furthermore, important topics of basic grammar are reviewed (exercises).

**Content**

Die im Kurs verwendeten Unterrichtsmaterialien werden den Teilnehmenden zugestellt bzw. in den Stunden verteilt oder auf einer elektronischen Unterrichtsplattform verfügbar gemacht.

**Objective**

Students gain an understanding of various aspects of a new topic and are able to analyse and contrast these aspects within a wider context.

**Objective**

The third part of the Norwegian-course aims at a further development of your active and passive language competence. You will finish the textbook and round it off by an individual assignment on a Norwegian theme.

**Objective**

You will be reading Norwegian literature with ease and discussing various themes both in speech and in writing.
### Abstract
This course gives participants an initial insight into the contemporary reality of the global Spanish-speaking community through journalistic texts.

The skills they practice in this approach include reading, writing, and oral interaction, and the course includes reading and writing activities and oral debates.

### Objective
Participants work on two areas: First, due the size of the Hispanic world, each week they focus on a nation or a region, thus gaining a deeper insight into that nation. Second, participants can choose to investigate various aspects of the Hispanic world, according to their own interests.

This course gives an overview of the societies that form the Hispanic world in two ways: On the one hand, the course looks at the perspectives of the various nations that comprise this international community, and on the other, it looks at various aspects that define this community, including its politics, news, traditions, and culture.

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<tr>
<th>Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>Hours</th>
<th>Level</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0827-01L</td>
<td>French B2-C1: Society and Current Issues</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>University lecturers</td>
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<tr>
<td>851-0849-03L</td>
<td>Brazilian Portuguese A2-B2: Urban Popular Music</td>
<td>W</td>
<td>2</td>
<td>1G</td>
<td>University lecturers</td>
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<tr>
<td>851-0846-02L</td>
<td>Spanish B2-C1: Language and Cinema</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>University lecturers</td>
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<tr>
<td>851-0856-04L</td>
<td>Spanish B2-C1: Grammar and Communication</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>University lecturers</td>
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Abstract
The main subject matter of this course includes a systematic discussion of the usage of past tenses; subordinate clauses; linking expressions; reported speech; periphrastic verb constructions; and verbs of change. In addition, participants undertake individual reading of various text types, with a particular emphasis on technical subjects and/or subjects related to their fields of study.

Objective
In this course, participants acquire oral and written academic communication skills; they acquire knowledge of the grammar areas relevant to B2-C1 level of the Common European Framework Reference for Languages; and they consolidate previously acquired grammar.

Does not take place this semester. No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 1 credit 1G University lecturers

Course fees:

Registration dates:

Abstract
This course offers participants the opportunity to carry out a "case study" based on a topical issue in order to practice and improve the four language skills by developing a fictitious but plausible scenario that requires the use of specific rhetorical, lexical, and pragmatic tools.

Objective
The main objective of this course is to give participants an opportunity to practice and improve the four language skills (speaking and listening comprehension, writing and reading comprehension) through "case studies." Participants present a complex topic and interact by defending a point of view and/or responding to objections. In addition, the course allows participants to develop their knowledge of Francophone culture (the media and the press).

851-0820-01L French B2-C1: Language and Cinema
Does not take place this semester. No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 1G University lecturers

Course fees:

Registration dates:

Abstract
This course offers participants a choice of films that reflect recent issues in order to raise their awareness of the ongoing concerns of contemporary French cinema, and also to enable them to improve their speaking skills, mainly through oral presentations.

Objective
The primary objective of this course is to develop participants’ listening comprehension skills and more specifically, to improve their understanding of implicit and cultural meanings of the films on the program. It further aims to raise participants’ awareness of the history, aesthetics, and contemporary issues of French cinema. The second objective of the course is to improve participants’ speaking skills, especially by giving them the opportunity to produce structured presentations and to express their personal, informed, and nuanced opinions.

851-0834-17L Spanish B2: Oral Interaction
Does not take place this semester. No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees:

Registration dates:

Abstract
Participants practice a range of oral interactions, such as casual and formal conversation, interviews, debates, negotiations, and presentations. They discuss current issues and their fields of study and/or work.

Objective
The course aims to expose participants to a range of conversational situations, providing them with tools that help them to improve their ability to perform various tasks linguistically and socially.

851-0826-04L Italian B2-C1: Language and Literature
Does not take place this semester. No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 2G University lecturers

Course fees:

Registration dates:

Abstract
The course approaches the Italian language through short stories, relevant both for their linguistic structures and content, which is related to historical and sociological realities typical for Italy. Participants deepen their lexical and syntactic competence by means of oral and written presentations, class discussions, reflections on the structures of the stories, and targeted exercises.

Objective
The course offers participants the opportunity to:
- Better understand complex literary texts
- Be able to grasp nuances of meaning expressed through certain lexical and syntactical choices more effectively
- Learn how to express themselves clearly and in a differentiated way
- Understand through short narrative texts some cultural and social realities typical of Italy

851-0826-05L Italian B2: Italian for Academic Purposes
Does not take place this semester. No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

W 2 credits 1G University lecturers

Course fees:

Registration dates:

Abstract
The course aims to expose participants to a range of conversational situations, providing them with tools that help them to improve their ability to perform various tasks linguistically and socially.
Abstract
In this course, participants examine and write/prepare various academic text genres, including scientific essays, abstracts, oral presentations, and handouts.

Objective
The course aims to deepen participants’ mastery of academic language. By reading scientific texts and listening to university lectures, participants analyze and study the linguistic structures of these text genres and learn specialist vocabulary from their field of study.

Course:

**851-0879-01L Chinese V 2.2+ □**

No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

**W 2 credits 2G**

University lecturers

Abstract
Chinese V requires level A2.2. of the Common European Framework of Reference. The goal of the course is for participants to communicate orally about selected topics from different areas.

Objective
The participants are able to talk about selected topics. The focus is on oral language skills. However, listening, reading and writing skills are also trained. Participants can work with texts or audios/videos using aids such as pop-up dictionaries and writing on the computer. Handwriting is not required. They learn to acquire the key vocabulary and to develop idioms for each topics. The students practice, for example, how to express a fact, their own opinion, criticism, agreement, concerns, etc. and how to respond to them.

Content
The vocabulary of 600 words, which was acquired in the courses I-IV, will be enlarged by another 150. Which means, that of the ten lessons of the book, five will have to be mastered.

The participants will learn 25 grammatical structures and the corresponding syntax. Furthermore they will learn 50 idiomatic phrases, and their respective use in everyday life. They will also acquire the competence to understand new characters from those already known.

We will train the faculty of understanding by listening, in order to enhance the chances to pass the listening test of the HSK 4 (B 2).

Lecture notes
This course will be supported by a module in OLAT. The participants will be asked to do some of their portfolios on OLAT.

Literature
HSK Standard Course 4, Teil 1, HSK标准教程4上 (含1MP3)
ISBN: 9787561939031 und HSK标准教程4上 练习册 (含1MP3)

Prerequisites / notice
It is mandatory that the course Chinese IV has been successfully completed. Or else, that a certificate of the HSK 3 examination in the last two years is provided.

GESS Science in Perspective - Key for Type

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

Key for Hours

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

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Molecular Genetics and Cell Biology

Abstract
This course teaches the basic principles of evolution, cell biology, molecular biology, genetics and developmental biology using the example of humans.

Objective
1) Students can explain the importance of evolution for the development of humans and diseases.
2) The students know the cell as the smallest unit of the body. They can explain how the functions of the cell are disturbed in certain diseases and where therapies intervene. They can describe the multiplication of cells in the body and show how errors in this multiplication can lead to diseases.
3) The students know DNA as the basis of life. They can explain how the DNA information is stored and how this information can be reproduced and protected from damage. They can describe how the information is read and translated into proteins. They can explain which mechanisms at the level of DNA, RNA and proteins can cause diseases.
4) Students can explain which technologies can be used to diagnose and treat diseases.
5) Students can explain how people differ genetically and know the molecular basis of these differences. They can explain how these differences can lead to diseases and why some of these differences do not affect diseases.
6) The students know the molecular causes of the most common hereditary diseases and can determine the probability of occurrence and transmission to offspring.
7) Students can explain the biochemical and molecular basis of human reproduction and know the basic principles of human embryonic development. The students can explain which mechanisms can be disturbed by a faulty development.

529-1001-03L
General Chemistry (for HST)

Abstract
The lecture deals with a number of basic chemistry concepts. These include (amongst others) chemical reactions, energy transfer during chemical reactions, properties of ionic and covalent bonds, Lewis structures, properties of solutions, kinetics, thermodynamics, acid-base equilibria, electrochemistry and properties of metal complexes.

Objective
The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.

Literature

252-0852-00L
Foundations of Computer Science

Abstract
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects.

Objective
The students learn to
- understand the role of computer science in science,
- to control computer and automate processes of problem solving by programming,
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

Content
1. The role of computer science in science
2. Introduction to Programming with Python
3. Modeling and simulations
4. Data management with lists and tables
5. Data management with a relational database
6. Introduction to Matrices

Lecture notes
All materials for the lecture are available at www.gdi.ethz.ch
Introduction to Health Sciences and Technology I

Lecturers: A. Caspar, R. Müller

Prerequisites / notice:
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Taught competencies:
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
- Adaptability and Flexibility
- Critical Thinking

Course Content:
- Health: differences health-disease-accident, diagnostics, therapy, prevention and rehabilitation, ICF, epidemiology.
- Technology: mechanics, measurement technology, automatic control engineering.
- Science: ethics, literature search, study design, tests, data analysis, data presentation.

First Year Examinations Part 2

Number of Credits: 4
ECTS: 2V+2U

Organic Chemistry I (for Biol./Pharm.Sc./HST) (401-0291-00L)

Objective:
Students should know the terms, models and classification systems used in health and disease; in addition, they should understand the foundations for the understanding of the relationship between structure and reactivity.

Content:
- Fundamentals of Organic Chemistry: molecular structure. Bonding and functional groups; nomenclature; resonance and aromaticity; stereoisomerism; stereoechemistry; conformation; bond strength; organic acids and bases; basic reaction thermodynamics and kinetics; reactive intermediates: carbanions, carbenium ions and radicals.

Lecture notes:
Printed lecture notes are available. Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry I" of the current semester (https://moodle-app2.let.ethz.ch).

Literature:

Prerequisites / notice:
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.
### Content

#### Eindimensionale diskrete Entwicklungen
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsrate
- Folgen und Grenzwerte

#### Funktionen in einer Variablen
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

#### Differentialerechnung (I)
- Veränderungsrate/-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

#### Integralerechnung (I)
- Stammfunktionen
- Integrationstechniken

#### Gewöhnliche Differentialgleichungen (I)
- Qualitative Beschreibung an Beispielen: Beschränkt, Logistisch, Gompertz
- Stationäre Lösungen
- Lineare DGL 1. Ordnung
- Trennung der Variablen

#### Lineare Algebra
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- Quadratische LGS und Determinante

---

**Lecture notes**

In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:

* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

---

**Literature**

Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Matheamtik für Naturwissenschaften, 2 Bände: Einführung in die Analysis, Einführung in die Lineare Algebra; Haupt-Verlag Bern, UTB.

**H. H. Storrer**
Einführung in die mathematische Behandlung der Naturwissenschaften I; Birkhäuser. Via ETHZ-Bibliothek.
https://link.springer.com/book/10.1007/978-3-0348-8598-0

**Ch. Blatter**
Lineare Algebra; VDF
auch als [pdf](<https://people.math.ethz.ch/~blatter/linalg.pdf>)

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**Prerequisites / notice**

### Second and Third Year Core Courses

#### Examination Blocks

#### Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Abstract**

Basic knowledge of the anatomy and physiology of tissues, of the embryonal and postnatal development, the sensory organs, the neuro-muscular system, the cardiovascular system and the respiratory system.

**Objective**

Basic knowledge of human anatomy and physiology and basics of clinical pathophysiology.

**Content**

Anatomy and Physiology I (fall term):
- Basics of cytology, histology, embryology; nervous system, sensory organs, muscles, cardiovascular system, respiratory system

Anatomy and Physiology II (spring term):
- digestive tract, endocrine organs, metabolism and thermoregulation, skin, blood and immune system, urinary system, circadian rhythm, reproductive organs, pregnancy and birth.
Prerequisites / notice

Requirements: 1st year, scientific part.
Part of the course is read and checked in English.

401-0293-00L Mathematics III
5 credits 3V+2U E. W. Farkas

Abstract
Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der Linearen Algebra und Einführung in die Systemanalyse und Modellbildung.

Objective
Vertiefung und Ausbau des Stoffes der Vorlesungen Mathematik I/II für die Anwendung in der Systemanalyse.

Content
- Euklidische Vektorräume, Skalarprodukt, Orthogonalität
- Entwicklung einer periodischen Funktion in eine Fourier-Reihe
- Komplexe Darstellung
- Anwendungen zur Lösung gewöhnlicher Differentialgleichungen, Reihenansätze.

Systeme linearer Differentialgleichungen 1. Ordnung
- Definition, allgemeine Lösungsmenge, Fundamentalsystem
- Bestimmung von Lösungen mittels Eigenvektoren, Fundamental- system im diagonalisierbaren Fall
- Exponential einer Matrix
- homogene lineare Differentialgleichungen n-ter Ordnung mit konstanten Koeffizienten.

Mathematische Modelle
- Begriffsbildung: (mathematisches) Modell, einführende Beispiele
- Lineare Kompartment-Modelle (Box-Modelle)

Lecture notes
Siehe Lernmaterial > Literatur

Literature
- Papula, L., Mathematik für Ingenieure und Naturwissenschaftler, Band 2, Vieweg und Teubner (2015), Kapitel 2 über Fourierreihen und Kapitel 4 über Partielle Differentialgleichungen
- A’Campo-Neuen, A., Skript über Gekoppelte Differentialgleichungen

Prerequisites / notice

Vorlesungen Mathematik I/II

401-0643-13L Statistics II
3 credits 2V+1U M. Kalisch

Abstract
Vertiefung von Statistikmethoden. Nach dem detailierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

Objective

Lecture notes
Siehe Lernmaterial > Literatur

Literature
- "Physik für Mediziner, Biologen, Pharmazeuten", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

Prerequisites / notice

Voraussetzung Mathematik I/II

402-0083-00L Physics I
4 credits 3V+1U K. S. Kirch

Abstract
This course is an introduction to classical physics, with special focus on applications in medicine.

Objective
Obtain an understanding of basic concepts in classical physics and their application (using mathematical pre-knowledge) to the solution of simple problems, including certain applications in medicine.

Obtain an understanding of relevant quantities and of orders of magnitude.

Content
- General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

Lecture notes
Will be distributed at the start of the semester.

Literature
"Physik für Mediziner, Biologen, Pharmazeutenv", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

Prerequisites / notice
Voraussetzung Mathematik I+II (Studiengänge Gesundheitswissenschaften und Technologie bzw. Humanmedizin) / Mathematik-Lehrveranstaltungen des Basisjahres (Studiengänge Chemie, Chemieingenieurwissenschaften bzw. Interdisziplinäre Naturwissenschaften)

Exam Block C

The examination block will not be offered until Spring Semester 2022.

Individual Subjects and Laboratory Courses

Number Title Type ECTS Hours Lecturers
376-0019-00L Laboratory Course in Medical Technology O 2 credits 2P J. G. Snedeker, O. Lambercy
The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to 3G.

Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to 3G.

Each experiment has its own tutorial and will be handed out to the students.

Online material is provided during the course.

The course aims at teaching and solidifying following topics:
- CAD
- FEM
- Product optimization
- Mechanical testing
- Software development in Python
- Hardware usage in robotics

The course is aimed at improving the students knowledge on certain topics such as programming in python and biomechanics, but also teaches new skills such as using CAD software, FEM and mechanical testing. The course is split into 6 different experiments, which will be completed in groups. The students will be assigned to groups at the beginning of the semester. 4 of the experiments will be geared towards the use case of designing a bone plate to bridge a critical size gap of a femur. The experiments are therefore 1) using CAD to reconstruct the initial condition and the bone plate 2) running a FEM in order to analyze the performance of the bone plate 3) with the knowledge of the FEM, optimizing the bone plate and 4) testing of the designed bone plate, the bone plate will be 3D printed. The remaining 2 experiments will 1) focus on programming a robotic arm used in rehabilitation engineering and 2) on the hardware usage of the robotic arm.

Each experiment has its own tutorial and will be handed out to the students.

Only motivation and curiosity is required.

**Focus Courses**

**Human Movement Sciences and Sports**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0203-00L</td>
<td>Movement and Sport Biomechanics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Taylor, R. List</td>
</tr>
<tr>
<td>376-0207-00L</td>
<td>Exercise Physiology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>C. Spengler, F. Gabe Beltrami,</td>
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<td>R. M. Rossi</td>
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</table>

**Biomedical Engineering**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>
### Objective

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

### Content


### Lecture notes

Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://lbb.ethz.ch/education/biomedical-engineering.html

### Literature

- Molecular Health Sciences

#### Table: Molecular Health Sciences

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W</td>
<td>6</td>
<td>4V</td>
<td>Y. Barral, D. Bopp, A. Hajnal, O. Voinnet</td>
</tr>
</tbody>
</table>

- Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

- The course covers the following topics:
  1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
  2. The concept of biocompatibility.
  3. Introduction into methodology used in biomaterials research and application.
  4. Introduction to different material classes in use for medical applications.

- The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

### ECTS

- Introduction into methodology used in biomaterials research and application.

- Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

- A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

- Literature:

- Handouts and references therin.

#### Molecular Health Sciences

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>551-0317-00L</td>
<td>Introduction into structural and functional aspects of the immune system.</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>M. Kopf, A. Oxenius</td>
</tr>
</tbody>
</table>

- Basic knowledge of the mechanisms and the regulation of an immune response.

- The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

- Basic knowledge of the mechanisms and the regulation of an immune response.
Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at “Lernmaterialien”

Literature
- Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Taught competencies

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

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

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

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

Neurosciences

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-1305-00L</td>
<td>Development of the Nervous System (University of Zurich)</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: BIO344

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cms/en/studies/application/deadlines.html

Abstract
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

Objective
On successful completion of the module the student should be able to
- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to
- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz as BIO344

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
Auxiliary tools:
None. Bring something to write and your student ID

376-1305-01L | Neural Systems for Sensory, Motor and Higher Brain Functions | W    | 3 credits | 2V    | G. Schratt, J. Bohacek, R. Fiore, W. von der Behrens, further lecturers |

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO343 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-
<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0002-00L</td>
<td>Product Design in Medical Engineering</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>S. J. Ferguson</td>
</tr>
<tr>
<td></td>
<td>Only for Health Sciences and Technology BSc, Programme Regulations 2017</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>This course will provide insight into various aspects of medical device design such as patient needs assessment, product specification, research and technical design, validation, regulatory affairs and clinical evaluation.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The goal of this lecture series is to enable the students to (i) identify the principal functional requirements for a medical device, (ii) to understand the mechanical properties of natural tissues and synthetic biomaterials, (iii) to apply this information and a basic knowledge of mechanics in the calculation of implant performance, (iv) to develop a plan for the pre-clinical evaluation and regulation of a new device.</td>
</tr>
</tbody>
</table>
|             | Content                                                              |      |      |        | 1. Introduction to Medical Technology  
2. Design Process  
3. Mechanics  
4. Mechanics of Materials  
5. Tissue Mechanics  
6. Prostheses: Biomechanics and Design  
7. Prostheses: Biomaterials, Surfaces and Wear  
8. Allografts: Heart Valves  
9. Preclinical Evaluation  
10. Regulatory Affairs (MepV, FDA, CE)  
11. Intellectual Property  
12. Group Work and Presentation |
|             | Lecture notes                                                        |      |      |        | https://moodle-app2.let.ethz.ch/course/view.php?id=180 |
| 551-0103-00L | Fundamentals of Biology II: Cell Biology                            | O    | 5    | 5V     | S. Werner, Y. Barral, U. Kutay, G. Schertler, U. Suter, I. Zemp |
|             | Only for - Biologie BSc (Programme Regulations 2013), - Pharmaceutical Sciences BSc (Programme Regulations 2013) - Health Sciences and Technology BSc (Programme Regulations 2017) |      |      |        |                            |
|             | Abstract                                                             |      |      |        | The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others. |
|             | Objective                                                            |      |      |        | The goal of this course is to provide students with a wide general understanding cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others. |
|             | Content                                                              |      |      |        | The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research. |
|             | Lecture notes                                                        |      |      |        | The lectures are presented in the Powerpoint format. These are available on the WEB for ETH students over the nethz (Moodle). Some lectures are available on the ETH WEB site in a live format (Livestream) at the above WEB site. |
|             | Prerequisites / notice                                               |      |      |        | Some of the lectures are given in the English language. Certain sections of the text-book must be studied by self-instruction. |
### Anatomy and Physiology I

**Number:** 376-0151-00L  
**Title:** Anatomy and Physiology I  
**Type:** O  
**ECTS:** 5 credits  
**Hours:** 4V  
**Lecturers:** D. P. Wolfer, K. De Bock, R. Fiore, S. Meissner, L. Slomianka, C. Spengler, M. Willecke

**Abstract:** Basic knowledge of the anatomy and physiology of tissues, of the embryonal and postnatal development, the sensory organs, the neuromuscular system, the cardiovascular system and the respiratory system.

**Objective:** Basic knowledge of human anatomy and physiology and basics of clinical pathophysiology.

**Content:** The lecture series provides a short overview of human anatomy and physiology

- Anatomy and Physiology I (fall term):
  - Basics of cytology, histology, embryology; nervous system, sensory organs, muscles, cardiovascular system, respiratory system
- Anatomy and Physiology II (spring term):
  - digestive tract, endocrine organs, metabolism and thermoregulation, skin, blood and immune system, urinary system, circadian rhythm, reproductive organs, pregnancy and birth.

**Prerequisites / notice**

Requirements: 1st year, scientific part.  
Part of the course is read and checked in English.

### Mathematics III

**Number:** 401-0293-00L  
**Title:** Mathematics III  
**Type:** O  
**ECTS:** 5 credits  
**Hours:** 3V+2U  
**Lecturers:** E. W. Farkas

**Abstract:** Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der Linearen Algebra und Einführung in die Systemanalyse und Modellbildung.

**Objective:** Vertiefung und Ausbau des Stoffes der Vorlesungen Mathematik I/II für die Anwendung in der Systemanalyse.

**Content:**

- Fourier-Reihen
- Euklidische Vektorräume, Skalarprodukt, Orthogonalität
- Entwicklung einer periodischen Funktion in eine Fourier-Reihe
- komplexe Darstellung
- Anwendungen zur Lösung gewöhnlicher Differentialgleichungen, Reihenansätze.

Systeme linearer Differentialgleichungen 1. Ordnung

- Definition, allgemeine Lösungsmenge, Fundamentalsystem
- Bestimmung von Lösungen mittels Eigenvektoren, Fundamental- system im diagonalisierbaren Fall
- Exponential einer Matrix
- homogene lineare Differentialgleichungen n-ter Ordnung mit konstanten Koeffizienten.

Mathematische Modelle

- Begriffsdefinition: (mathematisches) Modell, einführende Beispiele
- lineare Kompartment-Modelle (Box-Modelle)

Laplace-Transformation

- Grundbegriffe: Definition der Laplace-Transformation und Rück- transformation, Konvergenz des Laplace-Integrals
- Eigenschaften der Laplace-Transformation
- Anwendungen der Laplace-Transformation zur Lösung linearer Differentialgleichungen mit konstanten Koeffizienten.

Partielle Differentialgleichungen

- Definition, Randbedingungen, Anfangsbedingungen
- Diffusionsgleichung: Herleitung, Lösung an einfachen Beispielen
- Techniken: Separationsansätze, Basislösungen, Superpositionsprinzip

**Lecture notes**

Siehe Lernmaterial > Literatur

**Literature**

- Papula, L., Mathematik für Ingenieure und Naturwissenschaftler, Band 2, Vieweg und Teubner (2015), Kapitel 2 über Fourierreihen und Kapitel 4 über Partielle Differentialgleichungen
- A’Campo-Neuen, A., Skript über gekoppelte Differentialgleichungen

**Prerequisites / notice**

Vorlesungen Mathematik I/II

### Statistics II

**Number:** 401-0643-13L  
**Title:** Statistics II  
**Type:** O  
**ECTS:** 3 credits  
**Hours:** 2V+1U  
**Lecturers:** M. Kalisch

**Abstract:** Vertiefung von Statistikmethoden. Nach dem detailierten Fundament aus Statistik I liegt nun der Fokus auf konzeptueller Breite und konkreter Problemlösungsfähigkeit mit der Statistiksoftware R.

**Objective:**  

### Examination Block 3

**Number:** 376-0007-00L  
**Title:** Neuroanatomy and Neurophysiology  
**Type:** O  
**ECTS:** 2 credits  
**Hours:** 2V  
**Lecturers:** N. Wenderoth, D. P. Wolfer

**Abstract:** Advanced knowledge in anatomy and physiology of the nervous system.

**Note:** Does not take place this semester.  
*Only for Health Sciences and Technology BSc.  
Offered in the spring semester from HS21/FS22 onwards.*
Objective
Advanced knowledge of human anatomy and physiology and of molecular and pathophysiological aspects.

Content
- Anatomy of the central nervous system
- Function of the autonomic and the voluntary nervous system
- Sensomotoric integration
- Sensory physiology

402-0083-00L Physics I

Abstract
This course is an introduction to classical physics, with special focus on applications in medicine.

Objective
Obtain an understanding of basic concepts in classical physics and their application (using mathematical pre-knowledge) to the solution of simple problems, including certain applications in medicine.

Content
General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

Lecture notes
Will be distributed at the start of the semester.

Literature
"Physik für Mediziner, Biologen, Pharmazeuten", von Alfred Trautwein, Uwe Kreibig, Jürgen Hüttermann; De Gruyter Verlag.

Prerequisites / notice
Voraussetzung Mathematik I+II (Studiengänge Gesundheitswissenschaften und Technologie bzw. Humanmedizin) / Mathematik-Lehrveranstaltungen des Basisjahres (Studiengänge Chemie, Chemieingenieurwissenschaften bzw. Interdisziplinäre Naturwissenschaften)

★★★ Focus Courses

★★★ Human Movement Science and Sport

Number Title Type ECTS Hours Lecturers
376-0203-00L Movement and Sport Biomechanics W 4 credits 3G B. Taylor, R. List

Abstract
Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

Objective
Students are able to describe the human body as a mechanical system.

Content
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

376-0207-00L Exercise Physiology W 4 credits 3G C. Spengler, F. Gabe Beltrami, R. M. Rossi

Abstract
This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

Objective
The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

Content
History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular nad cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sexi differences relevant to exercise performance, exercise in hot and cold environment, children and adolescents in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

Lecture notes
Online material is provided during the course.

Literature
Wird in der Vorlesung bekannt gegeben.

Prerequisites / notice
Anatomy and Physiology I + II

★★★ Molecular Health Sciences

Number Title Type ECTS Hours Lecturers
551-0309-00L Concepts in Modern Genetics W 6 credits 4V Y. Barrai, D. Bopp, A. Hajnal, O. Voinnet

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

551-0317-00L Immunology I W 3 credits 2V M. Kopf, A. Oxenius

Abstract
Introduction into structural and functional aspects of the immune system.

Objective
Basic knowledge of the mechanisms and the regulation of an immune response.

Content:
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes:
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Literature:
- Kuby, Immunology, 9th edition, Freeman + Co., New York, 2020

Prerequisites / notice:
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Taught competencies:

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

Domain B - Method-specific Competencies
- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

Medical Technology

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
<tr>
<td>376-0021-00L</td>
<td>Materials and Mechanics in Medicine</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Zenobi-Wong, J. G. Snedeker</td>
</tr>
<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W</td>
<td>4 credits</td>
<td>3V</td>
<td>K. Maniera, M. Rottmar, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>

Abstracts:

Biomedical Engineering:
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Materials and Mechanics in Medicine:
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Biocompatible Materials:
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Lecture notes:
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

https://lbb.ethz.ch/education/biomedical-engineering.html

Academic Press
Objective
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

Lecture notes
Handouts are deposited online (moodle).

Literature

(available online via ETH library)

Handouts and references therein.

Neurosciences

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1305-00L</td>
<td>Development of the Nervous System (University of Zurich)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: BIO344

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

Objective
On successful completion of the module the student should be able to:
- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

Key skills
On successful completion of the module the student should be able to:
- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

Content
The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz as BIO344

Abstract
The course covers structural, plasticity and regeneration of the adult nervous system (NS) with focus on: sensory systems, cognitive functions, learning and memory, molecular and cellular mechanisms, animal models, and diseases of the NS.

Objective
The aim is to give a deepened insight into the structure, plasticity and regeneration of the nervous system based on molecular, cellular and biochemical approaches.

Content
The main focus is on the structure, plasticity and regeneration of the NS: biology of the adult nervous system; structural plasticity of the adult nervous system, regeneration and repair: networks and nerve fibers, regeneration, pathological loss of cells.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
Auxiliary tools:
None. Bring something to write and your student ID

376-1305-01L | Neural Systems for Sensory, Motor and Higher Brain Functions | W    | 3    | 2V    | G. Schratt, J. Bohacek, R. Fiore, W. von der Behrens, further lecturers

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO343 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract
The course covers the structure, plasticity and regeneration of the adult nervous system (NS) with focus on: sensory systems, cognitive functions, learning and memory, molecular and cellular mechanisms, animal models, and diseases of the NS.

Objective
The aim of this course is to give a deepened insight into the structure, plasticity and regeneration of the nervous system based on molecular, cellular and biochemical approaches.

Content
The main focus is on the structure, plasticity and regeneration of the NS: biology of the adult nervous system; structural plasticity of the adult nervous system, regeneration and repair: networks and nerve fibers, regeneration, pathological loss of cells.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle / OLAT.

551-0309-00L | Concepts in Modern Genetics | W    | 6    | 4V    | Y. Barat, D. Bopp, A. Hajnal, O. Voinnet

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module BIO348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-

Autumn Semester 2021
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

This course focuses on the concepts of classical and modern genetics and genomics. Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

- Introduction to mathematical signal processing and system theory.
- Lecture notes, problem set with solutions.

The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

The lecture will be taught in English.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0575-01L</td>
<td>Signals and Systems</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>A. Carron</td>
</tr>
<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson, N. Shamsudhin</td>
</tr>
<tr>
<td>151-0917-00L</td>
<td>Mass Transfer</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>S. E. Pratsinis, V. Mavrantzas, C.-J. Shih</td>
</tr>
<tr>
<td>227-0045-00L</td>
<td>Signals and Systems I</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td>327-0113-00L</td>
<td>Foundations of Materials Science I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>L. Isa</td>
</tr>
</tbody>
</table>

Abstracts:
- Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.
- The basic physical concepts for the description of materials are taught, partly in self-study, and applied in exercises. Basic atomistic and macroscopic concepts (e.g. phase diagrams, phase transformations, response functions) are introduced through examples. Selected topics are deepened in classroom lectures.

Lecture notes available on course website.
Objective
Students are able to
- name the basic concepts of materials science. (remember, 1)
- describe simple relations between atomic structure and macroscopic properties. (understand, 2)
- calculate basic material-specific quantities. (apply, 3)
- read and interpret phase diagrams, material characteristic (e.g. stress-strain) diagrams and Ashby plots (analyse, 4)

Content
Atomic structure
Crystalline structure and defects
Thermodynamics, phase diagrams and phase transformations
Diffusion
Mechanical and thermal properties of materials

Literature
Main textbook:
William D. Callister, Jr., David G. Rethwisch
Materials Science and Engineering - An Introduction

Alternatives:
Milton Ohring
Engineering Materials Science

James F. Shackelford
Introduction to Materials Science for Engineers

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376-0130-00L Laboratory Course in Exercise Physiology

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>3 credits</th>
<th>4P</th>
<th>C. Spengler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.</td>
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<tr>
<td>Content</td>
<td>Laboratory course: Various exercise tests assessing human performance and assessments of physiological responses to activity (examples are VO2max-test, Conconi-Tests, Determination of anaerobic threshold, Cooper-Test, 1-repetition maximum test, lactate minimum test), dynamometry, mechanography, body composition etc.). Insight into measurements in Sports Medicine.</td>
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<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Schmidt/Lang/Heckmann: Physiologie des Menschen, Springer-Verlag, Heidelberg</td>
<td>Kenney/Wilmore/Costill: Physiology of Sport and Exercise, Human Kinetics</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisite: Anatomy and physiology classes and lab course in physiology successfully completed (BWS students please contact C. M. Spengler)</td>
<td>Desirable: Exercise Physiology Lecture (concomitantly or passed; is selection criterion in case of more applications than lab spaces)</td>
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376-1033-00L History of Sports

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<thead>
<tr>
<th></th>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
<th>M. Gisler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Comprehension for development and changes of sports from the ancient world to the presence. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.</td>
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<tr>
<td>Content</td>
<td>Understanding for the development and adaptation of sports from the ancient world to present times.</td>
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<tr>
<td>Lecture notes</td>
<td>Ein Skript für die aktuelle Veranstaltung wird abgegeben.</td>
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376-1107-00L Sport Pedagogy

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
<th>C. Herrmann</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Development of pedagogical-psychological competences for the optimisation of future teaching activities.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Content</td>
<td>The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on &quot;pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education&quot;.</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>Teaching materials for the individual lectures are provided to the students via moodle.</td>
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376-1117-00L Sport Psychology

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<thead>
<tr>
<th></th>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
<th>H. Gubelmann</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Development of pedagogical-psychological competences for the optimisation of future teaching activities.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on &quot;pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education&quot;.</td>
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<tr>
<td>Lecture notes</td>
<td>Teaching materials for the individual lectures are provided to the students via moodle.</td>
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</tbody>
</table>
Analytical Competencies

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives assessed.

Sport and social change: developments and trends

Main Topics

- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Lecture notes

Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

Literature


376-1121-00L

Socio-Scientific Health Research: A Thematic Insight

W 2 credits 2G

O. Hämmig, R. Brauchli, S. T. Güntert

Abstract

Presentation of and work with different topics and particularly relevant focal points of socio-scientific health research as well as communication of contents and becoming more familiar with ways of thinking and working in socio-scientific health research.

Objective

The students get to know important and particularly health relevant socio-scientific topics, phenomena and problems and learn how to handle related issues and questions.

Content

There are many different socio-scientific disciplines or rather subdisciplines which deal with health relevant topics such as social or health psychology, medical or health sociology, gerontology, health economics, social epidemiology etc. They all belong to the health sciences and address societal and individual causes and conditions of health and disease. These causes and conditions include experiences such as social integration or isolation, poverty, migration, violence, social deprivation and discrimination, lifestyle, socialisation and family, personality, profession, unemployment, but also psychosocial aspects of biological characteristics like sex or age. The course gives an insight and overview of these social and personal determinants of health, which turned out to be highly relevant with regard to health, disease, life quality and mortality or life expectancy.

Prerequisites / notice

Willingness to be regularly present and to play an active part in the course.

376-1127-00L

Sociology of Sport

W 2 credits 2V

R. Bürgi, M. Lamprecht

Abstract

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

Objective

The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes any and becomes more differentiated in the process
- take current examples to highlight the sociological viewpoint of sport.

Content

Sport and social change: developments and trends

The economy and the media: dependencies, consequences, scandals

Social inequalities and distinctions: gender differences and group behavior

Conflicts and politics: sports organizations, doping, violence

Lecture notes

Selected materials for the lecture are available on the Moodle platform.

Literature


A detailed program with additional references will be delivered at the beginning of the lecture.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed

Domain C - Social Competencies
Sensitivity to Diversity assessed

Domain D - Personal Competencies
Critical Thinking assessed

376-1581-00L

Cancer: Fundamentals, Origin and Therapy

W 2 credits 2G

H. Nägeli

Abstract


Objective

Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.

Content

The lecture deals with problems of tumor epidemiology (causes, mortality, incidence). Cancer is delineated as a multi-step process. Classes of chemical compounds that induce cancer are discussed as well as the reactive metabolites that may be built from. Covalent binding to DNA is discussed and different types of mutations resulting thereof. A selection of proto-oncogenes and tumor suppressor genes is presented. Their function will be discussed as well as the changes which are found in these genes in tumor cells, starting from single nucleotide exchanges up to large deletions.

The reason for genetic predisposition to cancer will be discussed as well as cancer relevant aspects of cell cycle regulation. The role of tumor microenvironments and phenomenons like angiogenesis and metastasis are presented as well as the mechanisms that protect the genome from mutagenic damage. Further subjects address old and new strategies of cancer treatment. Personalised cancer treatment.

Lecture notes

Handouts with reproductions of all presented transparencies will be distributed.

Literature


additional information is given during the lecture

Prerequisites / notice

The lecture requires an active participation of the students. All students will participate in individual or group work focussing on specific subject of the lecture. Students will have ample time for preparation during lecture time.
Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**

- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**

- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

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**376-1661-00L Ethics of Life Sciences and Biotechnology**

**W 3 credits 2V A. Blasimme, E. Vayena**

**Abstract**

This semester course enables students to recognize, anticipate and address ethical issues in the domain of health sciences and their technological application. The students will acquire the necessary theoretical and analytic resources to develop critical thinking skills in the field of applied ethics and will practice how to use such resources to address concrete ethical issues in health sciences.

**Objective**

The course begins with an introductory lecture on ethics as a discipline and an overview of the most relevant approaches in the domain of applied ethics. The students will also be introduced to current theoretical accounts of technology and will start to appreciate the relevance of ethics especially with respect to new and emerging technologies. Usable analytic tools will also be provided, thus enabling the students to engage with the discipline in a practical way from the very onset of the semester.

The course will continue with thematic sessions covering a broad variety of topics all of which are relevant to the different study tracks offered by the department. In particular, the course will cover the following domains: digital health technologies and medical AI; food, nutrition and healthy longevity; biomedical engineering; genetics; neuroscience and Neurotechnologies; medical robotics; disability and rehabilitation; environmental ethics. The course will also include sessions on cross-cutting ethically relevant aspects of health sciences and technologies, namely: access to innovation, translational research, and the relation between science and public policy. All the topics of the course will be illustrated and interactively discussed through many case studies, offering the students the opportunity to prepare and present them, and to use them in individual as well as group exercises. Throughout the course, the students will have multiple opportunities to experiment with ethical argumentation and to practice their evolving skills.

**Content**

A. Identify ethical issues in in life sciences and biotechnology.
B. Analyze and critically discuss ethical issues in life sciences and biotechnology.
C. Become aware of relevant legal and public policy frameworks.
D. Distinguish different ethical approaches and argumentative strategies in applied ethics.
E. Recognize how ethical issues relate to different accounts of technology and innovation.
F. Develop a personal and critical attitude towards the ethical aspects of life sciences and their technological application.
G. Autonomous anticipate ethical issues.
H. Propose and communicate solutions to ethical challenges and dilemmas.

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**376-1716-00L Basics of Exercise Therapy**

**W 2 credits 2V K. Marshall**

**Number of participants limited to 30.**

Possible from the 5th semester on. Requirement: 376-1715-00L "Introduction to Exercise Therapy" passed.

**Abstract**

Basics of Exercise Therapy:
A: diagnostic, anamnesis, diagnostic of movement and function, assessments in exercise therapy, diagnostic of experience and behavior in relation to movement
B: biological-medical basics, pathophysiological Basics (internal, orthopedic and psychological diseases)

**Objective**

Students learn the assessments to plan an exercise-therapy-treatment.
They are able to use them. They’re able to integrate biological and medical basics.
They are able to prepareate a therapy-session

**Content**

Grundlagen der Diagnostik, Anamnese,
Beweglichkeits-, Funktionsdiagnostik
Sport- und Bewegungstherapeutische Testverfahren
Motorische Basisdiagnostik
Diagnostik bewegungsbezogenen Erlebens und Verhaltens
Biologisch-medizinische Grundlagen
Biomechanik (v.a. Gelenke), Pathophysiologische Grundlagen, Modelle der Methodik und Didaktik, Lektionsplanung

**Lecture notes**

Wird vor Semesterbeginn elektronisch zur Verfügung gestellt

**Literature**

- Schüle / Huber: Grundlagen der Sporttherapie, Deutscher Ärzteverlag, Köln 2012
- Deimel et al.: Neue aktive Wege in Prävention und Rehabilitation, Deutscher Ärzteverlag, Köln 2007

**Prerequisites / notice**

lecture "Introduction in Exercise Therapie" ist prerequisite

90% of the lections students must be present.

open-book-test in the last sessions at 20.12.2017

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**376-1717-00L Applied Basics in Sports and Exercise Therapy**

**W 2 credits 2V B. Spörrí Kälín, M. Gwerder**

**Number of participants limited to 30.**

Possible from the 5th semester on. Requirement: 376-1715-00L “Introduction to Exercise Therapy” passed.

Abstract
Communication skills and methods of psychoregulation applied to the area of Exercise and Sports Therapy.

Objective
The students are able to plan, lead through and evaluate conversations with patients. The students are familiar with a specific method of psychoregulation. The participants know different aspects of relationship formation (therapist/client) in therapeutic work.

Content
Communication and conversation: client-centered forms of conversation in theory and practice
Psychoregulative Methods: Theoretical and practical insight into various psychoregulative methods

Lecture notes
Documents will be distributed two weeks before lecture.

Prerequisites / notice
The courses “Exercise and Sports Therapy 1 and 2” have been completed successfully. A minimum of 90% of attendance if used as credits towards CAS SVGS. One seminar day in an institution/company specialized in reintegration of clients into the workforce.

376-1722-00L Spinal Cord Injury and Exercise

W 2 credits 2V C. Perret

Abstract
Intensive discussion concerning complications of a spinal cord injury and their consequences on trainability and exercise performance of persons sitting in a wheelchair. Overview on the clinical application of exercise testing as well as on the implementation of sport scientific findings to optimise performance of spinal cord injured subjects in rehabilitation and elite sports.

Objective
The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury

Content
The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury

Literature
General literature:
G.A. Zäch, H. G. Koch
Paraplegie - ganzheitliche Rehabilitation
Karger-Verlag, 2006
ISBN 3-8055-7980-2

V. Goosey-Tolfrey
Wheelchair sport: A complete guide for athletes, coaches and teachers
Human Kinetics, 2010

Y.C. Vanlandewijck, W.R. Thompson
The Paralympic Athlete
Wiley-Blackwell, 2011
ISBN 978-1-4443-3404-3

Liz Broad
Sports Nutrition for Paralympic Athletes, Second Edition
CRC Press 2019
ISBN 978-1-38908900-1

Y.C. Vanlandewijck, W.R. Thompson
Training and Coaching the Paralympic Athlete
ISBN 978-1-119-04433-8

Prerequisites / notice
Voraussetzung: Vorlesung Anatomie/Physiologie besucht!

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making not assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

529-0731-00L Nucleic Acids and Carbohydrates
W 6 credits 3G D. Hilvert, P. A. Kast, S. J. Sturla, H. Wennemers

Note for BSc Biology students: Only one of the two concept courses 529-0731-00 Nucleic Acids and Carbohydrates (autumn semester) or 529-0732-00 Proteins and Lipids (spring semester) can be counted for the Bachelor's degree.

Abstract
Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines
Objective

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Content

Structure, function and chemistry of nucleic acids and carbohydrates. DNA/RNA structure and synthesis; recombinant DNA technology and PCR; DNA arrays and genomics; antisense approach and RNAi; polymerases and transcription factors; catalytic RNA; DNA damage and repair; carbohydrate structure and synthesis; carbohydrate arrays; cell surface engineering; carbohydrate vaccines

Lecture notes

No script; illustrations from the original literature relevant to the individual lectures will be provided weekly (typically as handouts downloadable from the Moodle server).

Literature

Mainly based on original literature, a detailed list will be distributed during the lecture

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Problem-solving

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies

- Self-awareness and Self-reflection
- Self-direction and Self-management

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535-0230-00L Medicinal Chemistry I

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
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<tbody>
<tr>
<td>Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties. The molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions will be discussed and illustrated with examples.</td>
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<table>
<thead>
<tr>
<th>Literature</th>
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<tbody>
<tr>
<td>Will be provided in parts before each individual lecture.</td>
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Prerequisites / notice


535-0521-00L Pharmacology and Toxicology I

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
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<tbody>
<tr>
<td>The lectures will provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiologial and clinical aspects. Topics include disease-relevant macroscopic, microscopic, pathobiochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicology, contraindications and dosage of relevant drug classes. Basic principles of clinical pharmacology and pharmacotherapy will be covered.</td>
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<table>
<thead>
<tr>
<th>Literature</th>
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<tbody>
<tr>
<td>A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.</td>
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</tbody>
</table>

Prerequisites / notice

- Requirements: Knowledge of physical and organic chemistry, biochemistry and biology. Attendance of Medicinal Chemistry II in the spring semester.

535-0810-00L Gene Technology

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
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<tbody>
<tr>
<td>The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology. The course gives an overview of current state-of-the-art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the-art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.</td>
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<th>Literature</th>
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Prerequisites / notice

- Voraussetzungen: Abschluss Grundstudium
I) Genomics and transcriptomics

Methods and Techniques:
- Recombinant DNA technology
- Next generation sequencing methods, sequencing of genomes
- CRISPR technology

Application to human biology:
- Functional genomics/transcriptomics
- Principles of cancer, genetic diseases
- Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

II) Proteomics

Methods and Techniques:
- Protein cloning and expression
- The antibody molecule
- Measurement and determination of biomolecular interactions
- Protein characterization and engineering
- Modifications and radioactive labelling

Application to human biology:
- Protein therapeutics
- Proteomic approaches for identification of novel disease-related targets and biomarkers

III) Drug discovery: Protein-based libraries

- Immune repertoire mining
- Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

Lecture notes
The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| Critical Thinking | assessed |

535-0830-00L Pharmaceutical Immunology

Abstract
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Objective
Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Content
Chapters 1 - 11 of the Janeway’s Immunobiology, by Kenneth Murphy (9th Edition; Garland).

Literature
Janeway’s Immunobiology, by Kenneth Murphy (9th Edition).

[www.garlandscience.com]

551-0319-00L Cellular Biochemistry (Part I)

Abstract
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytokoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Objective
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

572-2120-00L Consumer Behaviour I

Abstract
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

Objective
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

572-4005-00L Food Microbiology I

Abstract
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.
Objective
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.

Content
1. History of Food Microbiology
   1.1. Short synopsis of foodborne microorganisms
2. Spoilage of Foods
3. Foodborne Disease
4. Food Preservation
   1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
   2.1. Origin of foodborne Microorganisms
   2.2. Bacteria
   2.3. Yeasts
   2.4. Molds
3. Microbial Spoilage of Foods
   3.1. Intrinsic and Extrinsic Parameters
   3.2. Meats, Seafoods, Eggs
   3.3. Milk and Milk Products
   3.4. Vegetable and Fruit Products
   3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
   3.6. Drinks and Canned Foods
4. Foodborne Disease
   4.1. Significance and Transmission of Foodborne pathogens
   4.2. Staphylococcus aureus
   4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
   4.4. Listeria monocytogenes
   4.5. Salmonella, Shigella, Escherichia coli
   4.6. Vibrio, Yersinia, Campylobacter
   4.7. Brucella, Mycobacterium
   4.8. Parasites
   4.9. Viruses and Bacteriophages
   4.10. Mycotoxins
   4.11. Bioactive Amines
   4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Literature
Recommendations will be given in the first lecture

752-6001-00L Introduction to Nutritional Science

Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

Objective
To introduce the students to the both macro- and micronutrients in relation to food and metabolism.

Content
The course is devided into two parts. The lectures on micronutrients are given by Prof. Zimmermann and the lectures on macronutrients are given by Prof. Wolfrum. Prof. Zimmermann discusses the micronutrients, including fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. Prof. Wolfrum introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism. The nutrients are described in relation to digestion, absorption and metabolism. Special aspects of homeostasis and homeorhesis are emphasized.

Lecture notes
There is no script. Powerpoint presentations will be made available.

Literature
Elmadfa I & Leitzmann C: Ernährung des Menschen
UTB Ulmer, Stuttgart, 4. überarb. Ausgabe 2004

Garrow JS and James WPT: Human Nutrition and Dietetics
Churchill Livingstone, Edinburgh, 11th rev. ed. 2005

752-6301-00L Nutrition-Related Physiology

Abstract
Gives the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.

Objective
Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relation to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand. For students with a background in medicine, pharmacy or biology, the course is useful as a review of previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.

Lecture notes
Handouts for each lecture will be uploaded to Moodle every week.

752-6403-00L Nutrition and Performance

Abstract
The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective
To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

Content
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes
Lecture slides and required handouts will be available on the ETH website (moodle).

Literature
Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.
General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

### GESS Science in Perspective

#### Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-HEST.

### Language Courses

see Science in Perspective: Language Courses ETH/UZH

### Sport Practical

Sport Practical Basic Education

Sport Practical Advanced Education

### Assessments

#### Health Sciences and Technology Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Code</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<table>
<thead>
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<th>Type</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

**ECTS** European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Educational Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in</td>
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<td></td>
<td>the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is</td>
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<td></td>
<td>about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical</td>
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<tr>
<td></td>
<td>studies on human learning and relates them to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand</td>
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<tr>
<td></td>
<td>the learning process. Against this background, theories and findings</td>
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<td></td>
<td>on the way humans process information and on human behaviour are</td>
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<td></td>
<td>prepared in such a manner that they can be used for planning and</td>
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<td></td>
<td>conducting lessons. Students additionally gain an understanding of</td>
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<td></td>
<td>what is going on in learning and behavioural research so that</td>
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<td></td>
<td>teachers are put in a position where they can further educate</td>
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<td></td>
<td>themselves in the field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte:</td>
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<tr>
<td></td>
<td>Lernen als Verhaltensänderung und als Informationsverarbeitung:</td>
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<tr>
<td></td>
<td>Das menschliche Gedächtnis unter besonderer Berücksichtigung der</td>
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<tr>
<td></td>
<td>Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion</td>
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<td></td>
<td>und Kompetenzerwerb unter besonderer Berücksichtigung des</td>
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<td></td>
<td>Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle</td>
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<td></td>
<td>von Emotion und Motivation beim Lernen; Interindividuelle</td>
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<tr>
<td></td>
<td>Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<tr>
<td>Lecture notes</td>
<td>Folien werden zur Verfügung gestellt.</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>1) Marcus Hasselhorn &amp; Andreas Gold (2006). Pädagogische Psychologie:</td>
<td></td>
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<tr>
<td></td>
<td>Erfolgreiches Lernen und Lehren. Stuttgart: Kohlhammer. 2) Jeanne</td>
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<td></td>
<td>Hall. 3) Greutmann, Saalbach, Stern (Hrsg.), (2020):</td>
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<td></td>
<td>Professionelles Handlungswissen für Lehrerinnen und Lehrer. Kohlhammer</td>
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<tr>
<td></td>
<td>Verlag</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This lecture is only apt for students who intend to enrol in</td>
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<td></td>
<td>the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;. It is about</td>
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<td></td>
<td>learning in childhood and adolescence.</td>
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<tr>
<td>851-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W D2)</td>
<td>W</td>
<td>2</td>
<td>3S</td>
<td>U. Markwalder, S. Maurer,</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 20.</td>
<td></td>
<td></td>
<td></td>
<td>S. Peteranderl-Rüschhoff</td>
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<tr>
<td>Abstract</td>
<td>In this class, students will learn concepts and skills for coping</td>
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<td></td>
<td>with psychosocial demands of teaching</td>
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<tr>
<td>Objective</td>
<td>Students possess theoretical knowledge and practical competences to</td>
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<td>be able to cope with the psychosocial demands of teaching.</td>
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<td>(1) They know relevant rules of conversation and conflict management</td>
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<td></td>
<td>and are able to apply them in an appropriate way in the school</td>
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<td>context (e.g. in parental talks).</td>
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<td>(2) They know core aspects of classroom management and know how</td>
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<td>to apply it concretely (e.g. promoting a positive learning atmosphere,</td>
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<td></td>
<td>avoiding disciplinary difficulties) and they are aware of possible</td>
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<td>contacts (e.g. illegal or psychological services).</td>
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<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects W</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or</td>
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<td>Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful participation</td>
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<td></td>
<td>in, or during enrollment in the course &quot;Human Learning (EW1)&quot;.</td>
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<tr>
<td>Objective</td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<td></td>
<td>- Get information about recent literature on learning and instruction</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
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<td>Enrolment only possible with matriculation in Teaching Diploma or</td>
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<td></td>
<td>Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td>Abstract</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und</td>
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<td></td>
<td>ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting</td>
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<td></td>
<td>is obligatory. It is required that all participants read the complete</td>
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<td>book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<tr>
<td>Objective</td>
<td>- Understanding of research methods used in the empirical human</td>
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<td></td>
<td>sciences</td>
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<td></td>
<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas,</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 30.</td>
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<td></td>
<td>C. M. Thurn</td>
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</tbody>
</table>
Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

**Objective**
- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0242-11L</td>
<td>Gender Issues In Education and STEM</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
</tr>
</tbody>
</table>

Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).

Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1)) in parallel, or to have successfully completed it.

**Objective**
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher’s work.

**Content**
Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

**Prerequisites / notice**
Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

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### Subject Didactics and Professional Training

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-8001-00L</td>
<td>Didactics of Health Sciences and Technology I</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>S. Maurer, S. Sinistaj</td>
</tr>
</tbody>
</table>

Enrolment at the earliest possible with the lecture 851-0240-00L “Human Learning”

**Abstract**
In this course students learn the principles and techniques of teaching singular lessons, based on scientific knowledge about learning. The aim is to plan, realize, evaluate and reflect lessons effectively and efficiently.

**Objective**
- Students know how to prepare, conduct and reflect a single lesson based on educational requirements.
- Students take the learning goals as a starting point considering previous knowledge as well as the professional environment and the ambitions of the learners.
- Students apply the basic teaching techniques of their subject area in a sensible way and know how to appropriately arrange the phases of learning.
- Students know how to simplify and present complex technical contents of their subject area.

**Taught competencies**

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

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

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

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<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>376-8008-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>6</td>
<td>13P</td>
<td>S. Maurer, S. Sinistaj</td>
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</tbody>
</table>

Only for Health Sciences and Technology TC students.

The teaching internship can just be visited if all other courses of TC are completed.

Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.

**Abstract**
Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
Objective

Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Further Subject Didactics

For students enrolled from HS 2019: The courses offered here are credited under the category «Subject Didactics and Professional Training».

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>376-8011-00L</td>
<td>Mentored Work Subject Didactics Health Sciences and O</td>
<td></td>
<td>2</td>
<td>4A</td>
<td>S. Maurer, S. Sinistaj</td>
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<tr>
<td></td>
<td>Only for Health Sciences and Technology TC students.</td>
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</table>

Abstract

The mentored paper is designed to bring together the findings from the FD1 and the FD2. By using various teaching techniques and methods a semester plan, which is based on various curricula will be elaborated for a given topic.

Objective

1. The students have planned a curriculum for a semester course.
2. Students reflect on formative and summative ways such a teaching unit to examine and implement parts of it.
3. The students have implemented parts of the semester curriculum.
4. The students deal with the question to what extend teaching techniques, teaching methods but also sequences of self-study must be involved in the planning.

Health Sciences and Technology TC - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Health Sciences and Technology Master
► Major in Human Movement Science and Sport

► Compulsory Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-0390-00L</td>
<td>Translational Science for Health and Medicine</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn, C. Wolfrum</td>
</tr>
<tr>
<td></td>
<td>Abstract: Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.</td>
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<td>Objective: After completing this course, students will be able to understand: Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)</td>
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<td>Content: What is translational science and what is it not? How to identify need? - Disease concepts and consequences for research - Basics about incidence, prevalence etc., and orphan indications - How to choose the appropriate research type and methodology - Ethical considerations including ethics application - Pros and cons of different types of research - Coordination of complex approaches incl. timing and resources - How to measure success? - Outcome variables - Improving the translational process - Challenges of communication? - How independent is translational science? - Academic boundary conditions vs. industrial influences</td>
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| 376-0302-01L | GCP Basic Course (Modules 1 and 2)              | O    | 1    | 1G    | G. Senti          |
|              | Abstract: The basic course in "Good Clinical Practice" (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities. |
|              | Objective: Students will get familiar with: - Key Ethics documents - (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA) - Sequence of research projects and project-involved parties - Planning of research projects (statistics, resources, study design, set-up of the study protocol) - Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH) - Roles and responsibilities of project-involved parties |
|              | Content: Module 1: Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form) Module 2: Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention |

► Electives

►► Electives Courses I

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-0221-00L</td>
<td>Methods and Concepts in Human Systems Neuroscience and Motor Control</td>
<td>W</td>
<td>4</td>
<td>3P</td>
<td>M. Schruff-Altamatt</td>
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<tr>
<td></td>
<td>Abstract: This course provides hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (nerve/brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students read scientific material, set up experiments, perform measurements in the lab, analyse data, apply statistics and write short reports or essays.</td>
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<td>Objective: This course will prepare students for experimental work as it is typically done during the master thesis. The goal is to gain hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (for example peripheral nerve stimulation, electrical and magnetic brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students will learn how to perform small scientific projects in this area. Students will work individually or in small groups and solve scientific problems which require them to perform measurements in human participants, extract relevant readouts from the data, apply appropriate statistics and interpret the results. They will also be required to write small essays and reports and they will get feedback on their writing throughout the course.</td>
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<td>Prerequisites / notice: Students are required to have successfully completed the course &quot;Neural control of movement and motor learning&quot; and to have basic knowledge of applied statistics.</td>
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<tr>
<td>376-0223-00L</td>
<td>Advanced Topics in Exercise Physiology</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>C. Spengler, G. D'Hulst, F. Gabe Beltrami</td>
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<tr>
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<td>Abstract: In this course, students read, present and discuss seminal publications in the area of exercise physiology. The focus lies on critical analysis of scientific content, conceptual as well as ethical aspects of publications. Students are trained in the most common scientific presentation techniques such as oral and poster presentations.</td>
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<td></td>
<td>Objective: Students gain further knowledge and a deeper understanding of concepts in exercise physiology. Emphasis is put on critical analysis and discussion of scientific publications as well as on improving scientific presentation skills.</td>
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</table>
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography.

**Introduction to Physical Activity for Health, including sedentary behavior**

Biomedical Engineering

There is no script. Powerpoint presentations will be made available on-line to students.

Material will be provided in moodle.

**Biomedical Imaging**

Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques.

**Clinical and Movement Biomechanics**

Measurement and modeling of the human movement during daily activities and in a clinical environment.

**Dietary Etiologies of Chronic Disease**

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Elective Courses II**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0385-10L</td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>S. Kozerke, K. P. Prüßmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.</td>
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<tr>
<td>Objective</td>
<td>- X-ray imaging</td>
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<tr>
<td>Content</td>
<td>- Computed tomography</td>
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<tr>
<td>Literature</td>
<td>Lecture notes and handouts</td>
<td></td>
<td></td>
<td></td>
<td>Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming</td>
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</tbody>
</table>

| 227-0386-00L | Biomedical Engineering          | W    | 4    | 3G    | J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong |
| Abstract    | Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined. |

On completion of this course students will be able to demonstrate:
1. knowledge of and critical awareness of the role of physical activity and sedentary behavior in the maintenance of health and the aetiology, prevention and treatment of disease.
2. thorough knowledge and critical awareness of current recommendations for physical activity, and current prevalence and trends of physical activity and associated diseases.
3. awareness of current national and international physical activity policies and how these impact on global challenges.

**Objective**

On completion of this course students will be able to demonstrate:
1. knowledge of and critical awareness of the role of physical activity and sedentary behavior in the maintenance of health and the aetiology, prevention and treatment of disease.
2. thorough knowledge and critical awareness of current recommendations for physical activity, and current prevalence and trends of physical activity and associated diseases.
3. awareness of current national and international physical activity policies and how these impact on global challenges.

**Content**

Introduction to Physical Activity for Health, including sedentary behavior

Physical activity epidemiology; concepts principles and approaches

Physical activity and all cause morbidity and mortality

Physical activity and chronic disease; Coronary heart disease, diabetes, bone health, cancer and obesity

Physical activity and brain health

Physical activity and sedentary behavior recommendations

Population prevalence of physical activity and sedentary behavior

Physical activity policies

Physical activity assessment

**Literature**

Core texts for this course are:


Selective journal articles from relevant journals such as Journal of Physical Activity and Health and Journal of Aging and Physical Activity

From the BSc-course the following book is recommended: 'Essentials of strength training and conditioning" T. Baechle, R. Earle (3rd Edition)

**Prerequisites / notice**

Successful completion of the Exercise Physiology Course.

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Objective

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

Content


Lecture notes

Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://ibb.ethz.ch/education/biomedical-engineering.html

227-0447-00L Image Analysis and Computer Vision

Objective

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes

Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice

Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

327-2125-00L Microscopy Training SEM I - Introduction to SEM

Abstract

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (http://www scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: (link will follow)

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Objective

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content

During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecture notes

Lecture notes will be distributed.

Literature


Prerequisites / notice

No mandatory prerequisites.
Good work design is crucial for individual and company effectiveness and a core element to be considered in organizational change.

The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding of themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

For PhD students, postdocs and others, a fee will be charged (http://www.scopem.ethz.ch/education/MTP.html).

All applicants will additionally register on this form: (link will follow) The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Lecture notes will be distributed.

Literature

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

Abstract
„Work Design and Organizational Change“ is a course that teaches how to design work that is effective and engaging for both employees and organizations. The course covers the basics of work design, including the importance of organization-technology interaction and its impact on organizational change.

Objective
- Know effects of work design on competence, motivation, and well-being
- Understand links between design of individual jobs and work processes
- Know basic processes involved in systematic organizational change
- Understand the interaction between organization and technology and its impact on organizational change
- Understand relevance of work design for company performance and strategy
- Know and apply methods for analyzing and designing work

Content
The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding of the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks by guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:
- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change management
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

Prerequisites / notice
A list of required readings will be provided at the beginning of the course.

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
The course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine.

Prerequisites
No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

Number of participants limited to 30

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

Objective 
1. Understanding and practical implementation of biosignal processes for imaging
2. Understanding of imaging techniques including radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging
3. Knowledge of computing, programming, modelling and simulation fundamentals
4. Computational and systems thinking as well as scripting and programming skills.
5. Understanding and practical implementation of emerging computational methods and their application in medicine including artificial intelligence, deep learning, big data, and complexity
6. Understanding of the emerging concept of personalised and in silico medicine
7. Encouragement of critical thinking and creating an environment for independent and self-directed studying

Content
Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine. For the imaging portion of the course, biosignal processing, radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging are covered. For the computing portion of the course, computing, programming, and modelling and simulation fundamentals are covered as well as their application in artificial intelligence and deep learning; complexity and systems medicine; big data and personalised medicine; and computational physiology and in silico medicine.

The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup: in the first part (TOEs: Tiny, Open-with-Restrictions courses focused on QuAlity and EffectiveES) students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A). Following the Q&A, the students will form small groups to acquire additional knowledge using online, python-based activities via JupyterHub or additionally distributed material and discuss their findings in teams. Learning outcomes will be reinforced with weekly Moodle assignments, to be completed during the flipped classroom portion.

Lecture notes
Stored on Moodle.

Prerequisites / notice
Lectures will be given in English.

363-0790-00L Technology Entrepreneurship 

Abstract
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

Objective
This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures.

Content
A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Lecture notes
See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

376-0130-00L Laboratory Course in Exercise Physiology

Abstract
Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that deepen the understanding of physiological processes in response to physical exertion.

Objective
Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climatic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.

Content
Laboratory course:
Various exercise tests assessing human performance and assessments of physiological responses to activity (examples are VO2max-test, Conconi-Tests, Determination of anaerobic threshold, Cooper-Test, 1-repetition maximum test, lactate minimum test), dynamometry, mechanography, body composition etc.). Insight into measurements in Sports Medicine.

Lecture notes
Tutorial on Laboratory Experiments in Exercise Physiology
(Editor: Exercise Physiology Lab)

Literature
Schmidt/Lang/Heckmann: Physiologie des Menschen, Springer-Verlag, Heidelberg

Kenney/Wilmore/Costill: Physiology of Sport and Exercise, Human Kinetics

Prerequisites / notice
Prerequisite:
Anatomy and physiology classes and lab course in physiology successfully completed (BWS students please contact C. M. Spengler)

Desirable:
Exercise Physiology Lecture (concomitantly or passed; is selection criterion in case of more applications than lab spaces)

376-0203-00L Movement and Sport Biomechanics

Abstract
Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

Objective
Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.

Content
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

Lecture notes
Online material is provided during the course.

376-0207-00L Exercise Physiology

Abstract
This course provides an overview over molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interactions of the different systems influencing factors, e.g. genetics, gender, age, altitude/depth, heat/cold, with respect to performance and health.

Objective
The aim of this course is to understand molecular and systemic aspects of neuromuscular, cardiovascular and respiratory adaptations to acute and chronic exercise as well as the interaction of the different systems regarding health-relevant aspects and performance in healthy people and persons with selected diseases. Furthermore, students will understand the influence of genetics, gender, age, altitude/depth, heat and cold on the named factors.

Content
History of Exercise Physiology, research methods, fibertype heterogeneity and its functional significance, neural control of muscle force, molecular nad cellular mechanisms of muscle adaptation to resistance, endurance and stretching exercise, interindividual variability in the response to training, cardiorespiratory and metabolic responses to acute and chronic exercise, sex differences relevant to exercise performance, exercise in hot and cold environment, children and adolescents in sport and exercise, exercise at altitude and depth, aging and exercise performance, exercise for health, exercise in the context of disease.

Autumn Semester 2021
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### Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects

**Prerequisites:**
- Advanced Physiology and Pathophysiology (376-0008-00L)
- Laboratory Course in Molecular Biology (376-0006-02L)

**Abstract**
The skeletal muscle biology field purposes to understand how muscles coordinate movement, regenerate following injury and adapt to exercise stimuli. The course will teach students to gain insights into the molecular aspects of muscle biology and exercise, in addition to hands-on experience in experimental techniques that are commonly used to research muscle regeneration and exercise.

**Objective**
The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. The course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.

**Content**
The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students - each one will focus on one of the following research topics:

- **Topic 1:** Molecular pathways that control muscle stem cell self-renewal and differentiation
- **Topic 2:** Genome engineering to correct genetic mutations that cause muscle diseases
- **Topic 3:** Muscle fiber composition, force production and insulin sensitivity
- **Topic 4:** Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:
1. Group 1: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
2. Group 2: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers. Immunofluorescence and PCR.
4. Group 4: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

**Prerequisites / notice**
- 376-0008-00L Advanced Physiology and Pathophysiology
- 376-0006-02L Laboratory Course in Molecular Biology

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### History of Sports

**Prerequisites:**
- 376-1028-00L The course in the ancient world to present times

**Abstract**
Comprehension for development and adaptation of sports from the ancient world to present times.

**Objective**

**Content**
Understanding for the development and adaptation of sports from the ancient world to present times.

**Lecture notes / literature**

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### Sport Pedagogy

**Prerequisites:**
- 376-1007-00L Teaching materials for the individual lectures are provided to the students via moodle.

**Abstract**
The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on "pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education".

**Objective**
Development of pedagogical-psychological competences for the optimisation of future teaching activities.

- Subject area of educational psychology
- Motivating students in physical education
- Building self-efficacy and strengthen the self-concept
- Promoting positive emotions and a positive attitude to anxiety
- Encouraging self-directed learning
- Leading classes and promoting cooperation
- Communicating with students efficiently
- Reflecting your own expectations critically
- Handling gender issues sensitively
- Promoting inclusion / Strengthening social and moral development
- Dealing with difficult students
- Evaluating achievements of students

**Lecture notes / literature**
Teaching materials for the individual lectures are provided to the students via moodle.

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### Sociology of Sport

**Prerequisites:**
- 376-1127-00L These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.
Sport Psychology

The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes and becomes more differentiated in the process
- take current examples to highlight the sociological view of sport.

Content
Sport and social change: developments and trends
- The economy and the media: dependencies, consequences, scandals
- Social inequalities and distinctions: gender differences and group behavior
- Conflicts and politics: sports organizations, doping, violence

Lecture notes
Selected materials for the lecture are available on the Moodle platform.

Literature

A detailed program with additional resources will be delivered at the beginning of the lecture.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Sensitivity to Diversity | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |

376-1117-00L  
Sport Psychology  
W  
2 credits  
2V  
H. Gubelmann

Abstract
This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

Objective
- Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' learning process is furthered by lecture and practice.

Content
- Main Topics
  - Introduction to sport psychology
  - Cognitions in sports: mental rehearsal and mental training
  - Emotions and stress
  - Motivation; goal-setting in sports
  - Career and career transition in elite sport
  - Coach-Athlete-Interaction
  - Psychological aspects of sport-injury rehabilitation
  - Group dynamics in sport

Lecture notes
Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

Literature


376-1151-00L  
Translation of Basic Research Findings from Genetics  
W  
3 credits  
2V  
M. Siegrist

Abstract
Recently, several start-up companies are aiming to translate basic molecular findings into new drugs/therapeutic interventions to slow aging or post-pone age-related diseases (e.g., Google founded Calico or Craig Venter's Human Longevity, Inc.). This course will teach students the basic skills to formulate their own ideas, design experiments to test them and explore more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Objective
The overall goal of this course is to be able to analyse current therapeutic interventions to identify an unmet need in molecular biology of aging and apply scientific thinking to discover new mechanisms that could be used as a novel therapeutic intervention. Learning objectives include:
1. Evaluate the current problem of our aging population, the impact of age-dependent diseases and current strategies to prevent these age-dependent diseases.
2. Analyse/compare current molecular/genetic strategies that address these aging problems.
3. Analyse case studies about biotech companies in the aging sector. Apply the scientific methods to formulate basic research questions to address these problems.
4. Generate own hypotheses (educated guess/idea), design experiments to test them, and map out the next steps to translate them.

Content
- Overview of aging and age-related diseases. Key discoveries in molecular biology of aging. Case studies of biotech companies addressing age-related complications. Brief introduction from bench to bedside with focus on start-up companies.

Prerequisites / notice
No compulsory prerequisites, but student should have basic knowledge about genetics and molecular biology.

376-1177-00L  
Human Factors I  
W  
3 credits  
2V  
M. Menozzi Jäckli, R. Huang, M. Siegrist

Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance.

Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved by addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchure, checklists, key articles etc. are uploaded in ILIAS
Applications of Cybernetics in Ergonomics

Abstract
Cybernetics systems have been studied and applied in various research fields, such as for applications in ergonomics. Topics discussed in this lecture (man-machine-interaction, performance in multi-modal interactions, quantification in gestalt principles for the use in product development, information processing) are deepened with exercises conducted at our labs.

Objective
To learn and practice cybernetics principles in interface designs and product development.

Content
- Fitt's law applied in manipulation tasks
- Hick-Hyman law applied in design of the driver assistance systems
- Vigilance applied in quality inspection
- Accommodation/vergence crosslink function
- Cross-link models in neurobiology- the ocular motor control system
- Human performance in optimization of production lines

Literature

Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Content
Introduction, problem definition, overview
- Rehabilitation of visual function
  - Anatomy and physiology of the visual sense
  - Technical aids (glasses, sensor substitution)
  - Retina and cortex implants
  - Rehabilitation of hearing function
  - Anatomy and physiology of the auditory sense
  - Hearing aids
  - Cochlea Implants
- Rehabilitation and use of kinesthetic and tactile function
  - Anatomy and physiology of the kinesthetic and tactile sense
  - Tactile/haptic displays for motion therapy (incl. electrical stimulation)
  - Role of displays in motor learning
  - Rehabilitation of vestibular function
  - Anatomy and physiology of the vestibular sense
  - Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
  - Cardiac Pacemaker
  - Phrenic stimulation, artificial breathing aids
  - Bladder stimulation, artificial sphincter
  - Brain stimulation and recording
  - Deep brain stimulation for patients with Parkinson, epilepsy, depression
  - Brain-Computer Interfaces
Literature

**Introductory Books:**

Selected Journal Articles and Web Links:

Prerequisites / notice

**Nanostructured Materials Safety**

**Abstract**
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

**Objective**
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

**Lecture notes**
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website

**Prerequisites / notice**

- course “Introduction to Toxicology”

**Biocompatible Materials**

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes
Handouts are deposited online (moodle).

Literature

(available online via ETH library)

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**376-1720-00L Application of MATLAB in the Human Movement Sciences**

**Abstract**

Students will learn to import, process and graphically present experimental data using the MATLAB computing environment. Both the data and the methods of analysis will be typical for experiments in Human Movement Science (i.e. kinematics, kinetics and electromyography).

**Objective**

Students will acquire the ability to independently load, plot, and process kinematic, kinetic and electromyographical data using the MATLAB computing environment.

**Content**

Drawbacks of Excel; Possibilities in MATLAB; Import of several data formats; Plot of one and more signals; Removing of an offset and filtering of data based on self-written functions; Normalisation and parametrisation of data; Reliability; Interpolation, Differentiation and Integration in MATLAB.

**Literature**

During the lecture, several electronically available MATLAB introductions are indicated. Course-specific scripts will be provided by the lecturer.

**Prerequisites / notice**

A Laptop with MATLAB installed (v2009 or higher) and wireless internet access is mandatory. Two students can share a laptop if necessary. A MATLAB student version can be obtained at Stud-IDES for free.

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**376-1722-00L Spinal Cord Injury and Exercise**

**Prerequisite:** Anatomy and Physiology

**Abstract**

Intensive discussion concerning complications of a spinal cord injury and their consequences on trainability and exercise performance of persons sitting in a wheelchair. Overview on the clinical application of exercise testing as well as on the implementation of sport scientific findings to optimise performance of spinal cord injured subjects in rehabilitation and elite sports.

**Objective**

Knowledge of the pathophysiology and the concomitant complications of a spinal cord injury and the consequences for physical exercise and trainability during rehabilitation as well as in recreational and elite sport.

**Content**

The following issues will be discussed: Epidemiology and etiology of spinal cord injury; complications and consequences of spinal cord injury; trainability/exercise physiology and spinal cord injury; history and organisation of wheelchair sports; elite sport and spinal cord injury

**Literature**

G.A. Zäch, H. G. Koch
Paraplegie - ganzheitliche Rehabilitation
Karger-Verlag, 2006
ISBN 3-8055-7980-2

V. Goosey-Tolfrey
Wheelchair sport: A complete guide for athletes, coaches and teachers
Human Kinetics, 2010

Y.C. Vanlandewijck, W.R. Thompson
The Paralympic Athlete
Wiley-Blackwell, 2011
ISBN 978-1-4443-3404-3

Liz Broad
Sports Nutrition for Paralympic Athletes, Second Edition
CRC Press 2019

Y.C. Vanlandewijck, W.R. Thompson
Training and Coaching the Paralympic Athlete
ISBN 978-1-119-04433-8

**Prerequisites / notice**

Voraussetzung: Vorlesung Anatomie/Physiologie besucht!
Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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**376-1723-00L Big Data Analysis in Biomedical Research**

**W 4 credits 2V+2U** E. Araldi, M. Ristow

**Abstract**
Biomedical datasets are increasing in size and complexity, and discoveries arising from their analysis have important implications in human health and biotechnological advances. While the potential of biomedical dataset analysis is considerable, preclinical researchers often lack the computational tools to analyze them. This course will provide the basis of data analysis of large biomedical data.

**Objective**
This course aims to provide practical tools to analyze large biomedical datasets, and it is tailored towards experimental researchers in the life sciences with minimal prior programming experience, but with a strong interest in exploring big data to solve own research problems. Through theoretical classes, practical demonstrations, in class exercises and homework, the participants will master computational methods to independently manipulate large datasets, effectively visualize big data, and analyze it with appropriate statistical tools and machine learning approaches. For the final assessment, students will conduct an independent data analysis project based on a biomedical problem of their choosing and using publicly available population-based biomedical datasets.

**Content**
While learning the programming skills needed to manipulate and visualize the data, participants will learn the statistical and modeling approaches for big data analysis. The course will cover:

- Basis of Python programming and UNIX;
- High performance computing;
- Manipulation and cleaning of large datasets with Pandas;
- Visualization tools (Matplotlib, Seaborn);
- Machine learning and numerical libraries (SciPy, NumPy, Statsmodels, Scikit-Learn);
- Statistical analysis and modeling of big data, and applications to biomedical datasets (statistical learning, distributions, linear and logistic regressions, principal component analysis, clustering, classification, time series analysis, tree-based methods, predictive models).

**Prerequisites / notice**
Basic understanding of mathematics and statistics, as taught in basic courses at the Bachelor’s level.

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**376-1974-00L Colloquium in Biomechanics**

**W 2 credits 2K** B. Helgason, S. J. Ferguson, R. Müller, J. G. Snedeker, B. Taylor, M. Zenobi-Wong

**Abstract**
Current topics in biomechanics presented by speakers from academia and industry.

**Objective**
Getting insight into actual areas and problems of biomechanics.

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**376-1985-00L Trauma Biomechanics**

**W 4 credits 2V+1U** K.-U. Schmitt, M. H. Muser

**Abstract**
Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.

**Objective**
Introduction to the basic principles of trauma biomechanics.

**Content**
This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

**Lecture notes**
Handouts will be made available.

**Literature**
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

Abstract
This lecture introduces the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

Literature

Prerequisites / notice
A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

Abstract
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.

Literature
E. J. Windhab, S. Michlig Gonzalez, T. Wooster

Prerequisites / notice
Number of participants limited to 15.

Abstract
A “cook-and look” approach to process design is no longer applicable in the current environmental, nutritional and competitive constraints. The modern R&D chemical/food engineer should have a clear focus on the desired structure that needs to be achieved to design a process line or a processing equipment, coupled with in depth knowledge of the processed materials.

Objective
The objective of this course is to highlight the intimate links between human physiology and product sensory and nutritional functions. To optimize these functions, an understanding of the physiological functions that interact and encode the actions of those product structures must be well understood.

The students will be exposed to this interplay all along the GI tract, including taste, aroma and texture perception, swallowing mechanics and gastro intestinal digestion with an engineering or physical sciences angle.

Abstract
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.
Concepts and Theories

Human Health, Nutrition and Environment: Term Concepts and Theories

Acquisition of knowledge in the field of the review paper not assessed

Creative Thinking

Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The not assessed

Nutrition and Performance

To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise. General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

Analytical Competencies

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics. The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

Domain A - Subject-specific Competencies

Concepts and Theories assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving not assessed

Project Management not assessed

Communication not assessed

Cooperation and Teamwork not assessed

Creative Thinking not assessed

Critical Thinking assessed

752-6151-00L

Public Health Concepts

W 3 credits 2V R. Heusser

Abstract

The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

Objective

At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

Domain A - Subject-specific Competencies

Concepts and Theories assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving not assessed

Project Management not assessed

Communication not assessed

Cooperation and Teamwork not assessed

Domain C - Social Competencies

Creative Thinking not assessed

Critical Thinking assessed

752-6403-00L

Nourishment and Performance

W 2 credits 2V S. Mettler, M. B. Zimmermann

Abstract

The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective

To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

Content

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intense exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise.

Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes

Handouts are provided to students in the classroom.

Literature

Lecture slides and required handouts will be available on the ETH website (moodle).

Prerequisites / notice

General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

The overall goal of the course is to introduce students to translational science and related features into their future projects. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)
This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

### Content
What is translational science and what is it not?
- Disease concepts and consequences for research
- Basics about incidence, prevalence etc., and orphan indications
- How to choose the appropriate research type and methodology
- Ethical considerations including ethics application
- Pros and cons of different types of research
- Coordination of complex approaches incl. timing and resources
- How to measure success?
- Outcome variables
- Improving the translational process
- Challenges of communication?
- How independent is translational science?
- Academic boundary conditions vs. industrial influences

Positive and negative examples will be illustrated by distinguished guest speakers.

#### 752-6105-00L  Epidemiology and Prevention
- **Type**: W
- **ECTS**: 3 credits
- **Hours**: 2V
- **Lecturers**: M. Puhan, R. Heusser

**Abstract**
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

**Objective**
- The module Epidemiology and prevention describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.
Taught competencies

- Domain A - Subject-specific Competencies
  Concepts and Theories: assessed
- Domain B - Method-specific Competencies
  Analytical Competencies: assessed
  Decision-making: assessed
  Problem-solving: not assessed
  Project Management: not assessed
- Domain C - Social Competencies
  Communication: not assessed
  Cooperation and Teamwork: not assessed
- Domain D - Personal Competencies
  Creative Thinking: not assessed
  Critical Thinking: assessed

752-6151-00L Public Health Concepts

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Objective

At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

Content

Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, iodine/PH nutrition).

Lecture notes

Handouts are provided to students in the classroom.

Abstract

The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed

Domain B - Method-specific Competencies

- Analytical Competencies: assessed
- Decision-making: assessed

Domain C - Social Competencies

- Communication: not assessed

Domain D - Personal Competencies

- Creative Thinking: not assessed
- Critical Thinking: assessed

Module: Infectious Diseases

Number | Title | Type | ECTS | Hours | Lecturers |
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<tr>
<td>701-0263-01L</td>
<td>Seminar in Evolutionary Ecology of Infectious Diseases</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. R. Regös, S. Bonhoeffer</td>
</tr>
</tbody>
</table>

Abstract

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

Objective

Obtain a detailed understanding of:
- the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- the recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells,
- Optimization of B cell responses by intelligent design of new vaccines

Content

- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature

Documents of the lectures are available for download at: https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites notice

Immunology I and II recommended but not compulsory

Number | Title | Type | ECTS | Hours | Lecturers |
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<tr>
<td>701-1471-00L</td>
<td>Ecological Parasitology</td>
<td>W</td>
<td>3</td>
<td>1V+1P</td>
<td>J. Jokela, C. Vorburger</td>
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Abstract

Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.

Waiting list will be deleted on October 1st, 2021.
The focus is on primary literature, but for some parts the following text books provide good background information:

2G

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant Evolutionary Medicine for Infectious Diseases

W

Lectures:

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i)

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature

The focus is on primary literature, but for some parts the following text books provide good background information:

Schmid Hempel 2011 Evolutionary Parasitology

Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

701-1703-00L

Evolutionary Medicine for Infectious Diseases

W

3 credits

2G

A. Hall

Number of participants limited to 35.

Waiting list will be deleted October 3rd, 2021.

Abstract

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.

Objective

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.

Content

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (< 20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature

The focus is on primary literature, but for some parts the following text books provide good background information:

Schmid Hempel 2011 Evolutionary Parasitology

Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

752-4009-00L

Molecular Biology of Foodborne Pathogens

W

3 credits

2V

M. Loessner, M. Schmelcher, M. Schuppler, E. Wetter Slack

Prerequisites

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

Content

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions toxins will virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Prerequisites / notice

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break !

Module: Nutrition and Health

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
752-2122-00L | Food and Consumer Behaviour | W | 2 | 2V | M. Siegrist, C. Hartmann
Abstract | This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.
Objective | The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues
752-5103-00L | Functional Microorganisms in Foods | W | 3 | 2G | C. Lacroix, A. Geinaert, A. Greppi
Abstract | This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.
Objective | To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefitting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.
Content
This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- **Probiotics and Prebiotics:** human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- **Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety:** antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- **Legal and protection issues related to functional foods**
- **Industrial biotechnology of flavor and taste development**
- **Safety of food cultures and probiotics**

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

Lecture notes
Copy of the power point slides from lectures will be provided.

Literature
A list of topics for group projects will be supplied, with key references for each topic.

This lecture requires strong basics in microbiology.

### Module: Environment and Health

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<tr>
<td>376-1353-00L</td>
<td><strong>Dietary Etiologies of Chronic Disease</strong></td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>M. B. Zimmermann</td>
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</table>

**Abstract**
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**
There is no script. Powerpoint presentations will be made available on-line to students.

**Literature**
To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

#### Major in Medical Technology

#### Compulsory Courses

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<th>Number</th>
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<tr>
<td>376-0300-00L</td>
<td><strong>Translational Science for Health and Medicine</strong></td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn, C. Wolfrum</td>
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</table>

**Abstract**
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

**Objective**
After completing this course, students will be able to understand:
- Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)
Students will get familiar with:
- ECTS
- Lecture notes and handouts

Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The objective of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Module 1:
The course will cover topics such as:
- Microrobotic systems
- Design and fabrication
- Actuation and control
- Applications in biology and medicine
- Materials and fabrication methods
- Low Reynolds number flows
- Electromagnetism
- Electrostatics
- Scaling laws at micro/nano scales

Module 2:
- Roles and Responsibilities of project-involved parties
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Approval of research protocols
- Roles and Responsibilities of project-involved parties

Students will learn how to:
- Classify research projects according the risk-based approach of the HRA
- Write a study protocol
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data

Content
- Module 1: Research and Research Ethics, Guidelines, (international Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Study protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form)
- Module 2: Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention

ELECTIVE COURSES

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<td>151-0604-00L</td>
<td>Microrobotics</td>
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Abstract
- Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The objective of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
- The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
- Main topics of the course include:
  - Scaling laws at micro/nano scales
  - Electrostatics
  - Electromagnetism
  - Low Reynolds number flows
  - Observation tools
  - Materials and fabrication methods
  - Applications of biomedical microrobots

Prerequisites / notice
- The lecture will be taught in English.

Abstract
- Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

Objective
- To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

Content
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

Prerequisites / notice
- Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming
Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course focuses on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view.

Objective
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

Content
- Potentiometric sensors
  - Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
  - Principles of operation of ion-selective electrodes
- Amperometric sensors and bioelectric potentials
  - Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
  - Principles of operation of amperometric sensors
  - Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)
- Channels, amplification, signal gating, and patch clamp Y4
- Action potentials and impulse propagation
- Functional electric stimulation and recording
  - MEA and CMOS based recording
  - Applying potential in liquid - simulation of fields and relevance to electric stimulation
- Neural networks memory and learning
  - Plasmonic sensing
  - Optical sensors and their applications
  - Differential equation for optical waveguides
- Optical biosensors
  - Fundamentals of optical probes for measuring and manipulating molecular and cellular processes
  - Optical sensors and their applications
- Engineering principles of optical probes for measuring and manipulating molecular and cellular processes
- Basic notions of molecular adsorption and electron transfer
  - Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
  - Electron transfer: Marcus theory, Gerischer theory
- Potentiometric sensors
  - Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
  - Principles of operation of ion-selective electrodes
- Amperometric sensors and bioelectric potentials
  - Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
  - Principles of operation of amperometric sensors
  - Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions
Prerequisites / notice
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.
The course language is English.

### 227-0939-00L Cell Biophysics W 6 credits 4G T. Zambelli

**Abstract**
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.

**Objective**
Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life's mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann's law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

**Content**
- Basics of theory of probability
- Boltzmann's law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

**Lecture notes**
No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock – 18.00) will be proposed via zoom to solve together the exercises of the previous week.

**Literature**

**Prerequisites / notice**
Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.
## 227-0965-00L Micro and Nano-Tomography of Biological Tissues

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

**Abstract**
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

**Content**
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**
Available online

**Literature**
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

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## 227-0969-00L Methods & Models for fMRI Data Analysis

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

**Abstract**
This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

**Objective**
To obtain in-depth knowledge of the theoretical foundations of SPM and DCM and of their practical application to empirical fMRI data.

**Content**
This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Lecture notes**
Available online

**Literature**
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

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## 327-0505-00L Surfaces, Interfaces and their Applications I

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: not assessed

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

**Abstract**
After being introduced to the physical/chemical principles and importance of surfaces and interfaces, the student is introduced to the most important techniques that can be used to characterize surfaces. Later, liquid interfaces are treated, followed by an introduction to the fields of tribology (friction, lubrication, and wear) and corrosion.

**Objective**
- To gain an understanding of the physical and chemical principles, as well as the tools and applications of surface science, and to be able to choose appropriate surface-analytical approaches for solving problems.
- To choose appropriate surface-analytical approaches for solving problems.

**Content**
Introduction to Surface Science
- Physical Structure of Surfaces
- Surface Forces (static and dynamic)
- Adsorbates on Surfaces
- Surface Thermodynamics and Kinetics
- The Solid-Liquid Interface
- Electron Spectroscopy
- Vibrational Spectroscopy on Surfaces
- Scanning Probe Microscopy
- Introduction to Tribology
- Introduction to Corrosion Science

**Lecture notes**
Script Download:
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

**Literature**
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

**Prerequisites / notice**
- Chemistry:
  - General undergraduate chemistry
  - including basic chemical kinetics and thermodynamics
- Physics:
  - General undergraduate physics
  - including basic theory of diffraction and basic knowledge of crystal structures
Microscopy Training SEM I - Introduction to SEM

Objective
Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast and imaging modes
- Sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Lectures:
- Introduction on Microscopy and instrumentation
- Electron sources, electron lenses and probe formation
- Beam/specimen interaction, image formation, image contrast and imaging modes
- Sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

No mandatory prerequisites.

Microscopy Training TEM I - Introduction to TEM

Objective
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

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

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

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real-world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Design Thinking: Human-Centered Solutions to Real World Challenges

Abstract

The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as an one-week, a three-week, and a final six-week project with an external project partner.

Objective

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real-life examples and cases.

Content

See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

Lecture slides and case material

Prerequisites / notice

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

363-0790-00L Technology Entrepreneurship

2 credits

2V

W

F. Hacklin

Abstract

Technology Ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

Objective

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures. A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

Content

See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

Lecture slides and case material

363-1065-00L Design Thinking: Human-Centered Solutions to Real World Challenges

5 credits

5G

W

S. Brusoni

Abstract

Does not take place this semester.

Objective

During the course, students will learn about different design thinking methods and tools. This will enable them to:

- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Content

The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as an one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem-solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

Prerequisites / notice

Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session. Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbrester to learn about the requirements of the class.

376-0021-00L Materials and Mechanics in Medicine

4 credits

3G

W

M. Zenobi-Wong, J. G. Snedeker

Abstract

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Objective

Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering, mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Content

Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.

Lecture notes


376-0121-00L Multiscale Bone Biomechanics

6 credits

4S

W

R. Müller, X.-H. Qin

Abstract

Number of participants limited to 30

Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine.
The overall goal of this course is to be able to analyse current therapeutic interventions to identify an unmet need in molecular biology of exercise and skeletal muscle biology. The course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine. For the imaging portion of the course, biosignal processing, imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging are covered. For the computing portion of the course, computing, programming, and modelling and simulation fundamentals are covered as well as their application in artificial intelligence and deep learning; complexity and systems medicine; big data and personalised medicine; and computational physiology and in silico medicine.

The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup: in the first part (TORQUEs: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturer may prepare additional knowledge using online, python-based activities via JupyterHub or additionally distributed material and discuss their findings in teams. Learning outcomes will be reinforced with weekly Moodle assignments, to be completed during the flipped classroom portion.

The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students- each one will focus on one of the following research topics:

- **Topic 1**: Molecular pathways that control muscle stem cell self-renewal and differentiation
- **Topic 2**: Genome engineering to correct genetic mutations that cause muscle diseases
- **Topic 3**: Muscle fiber composition, force production and insulin sensitivity
- **Topic 4**: Amino acid sensitivity in skeletal muscle following exercise

The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lecture by the professors in addition to a journal club presentation by the students. The journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

Select practical methods that the proposed course will teach include:

- **i. Group 1**: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screening, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
- **ii. Group 2**: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers, Immunofluorescence and PCR.
- **iii. Group 3**: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, Immunofluorescence and western blot.
- **iv. Group 4**: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

**Prerequisites / notice**
- Prerequisites: 376-0008-00L Advanced Physiology and Pathophysiology
- Lectures will be given in English.
- Number of participants limited to 30.
- Does not take place this semester.
- Autumn Semester 2021

**Objective**

- Understanding and practical implementation of biosignal processes methods for imaging
- Understanding of imaging techniques including radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging
- Knowledge of computing, programming, modelling and simulation fundamentals
- Computational and systems thinking as well as scripting and programming skills
- Understanding and practical implementation of emerging computational methods and their application in medicine including artificial intelligence, deep learning, big data, and complexity
- Understanding of the emerging concept of personalised and in silico medicine
- Encouragement of critical thinking and creating an environment for independent and self-directed studying

**Content**

- Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine. For the imaging portion of the course, biosignal processing, imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging are covered. For the computing portion of the course, computing, programming, and modelling and simulation fundamentals are covered as well as their application in artificial intelligence and deep learning; complexity and systems medicine; big data and personalised medicine; and computational physiology and in silico medicine.

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  - **ii. Group 2**: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers, Immunofluorescence and PCR.
  - **iii. Group 3**: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, Immunofluorescence and western blot.
  - **iv. Group 4**: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

**Prerequisites / notice**
- Prerequisites: 376-0008-00L Advanced Physiology and Pathophysiology

**Abstract**

- The skeletal muscle biology field purposes to understand how muscles coordinate movement, regenerate following injury and adapt to exercise stimuli. In this course, the students will acquire insights into the molecular aspects of muscle biology and exercise, in addition to gaining hands-on experience in experimental techniques that are commonly used to research muscle regeneration and exercise.

**Objective**

- The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in molecular biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.

**Content**

- The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students- each one will focus on one of the following research topics:
  - **Topic 1**: Molecular pathways that control muscle stem cell self-renewal and differentiation
  - **Topic 2**: Genome engineering to correct genetic mutations that cause muscle diseases
  - **Topic 3**: Muscle fiber composition, force production and insulin sensitivity
  - **Topic 4**: Amino acid sensitivity in skeletal muscle following exercise

- The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lecture by the professors in addition to a journal club presentation by the students. The journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session.

- For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.

- Select practical methods that the proposed course will teach include:
  - **i. Group 1**: tissue culture, isolation of muscle stem cells via FACS, differentiation of muscle stem cell into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, Immunofluorescence.
  - **ii. Group 2**: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers, Immunofluorescence and PCR.
  - **iii. Group 3**: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, Immunofluorescence and western blot.
  - **iv. Group 4**: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

**Prerequisites / notice**
- Prerequisites: 376-0008-00L Advanced Physiology and Pathophysiology

**Abstract**

- Recently, several start-up companies are aiming to translate basic molecular findings into new drugs/therapeutic interventions to slow aging or post-pone age-related diseases (e.g., Google founded Calico or Craig Venter's Human Longevity, Inc.). This course will teach students the basic skill sets to formulate their own ideas, design experiments to test them and explains the next steps to translate

**Objective**

- The overall goal of this course is to be able to analyse current therapeutic interventions to identify an unmet need in molecular biology of aging and apply scientific thinking to discover new mechanisms that could be used as a novel therapeutic intervention.

- Learning objectives include:
  1. Evaluate the current problem of our aging population, the impact of age-dependent diseases and current strategies to prevent these age-dependent diseases.
  2. Analyse/compare current molecular/genetic strategies that address these aging problems.
  3. Analyse case studies about biotech companies in the aging sector. Apply the scientific methods to formulate basic research questions to address these problems.
  4. Generate own hypotheses (educated guess/idea), design experiments to test them, and map out the next steps to translate them.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>4</td>
<td>V. Vogel, further lecturers</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td>Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies. The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries. Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.</td>
</tr>
<tr>
<td>376-1177-00L</td>
<td>Human Factors I</td>
<td>3</td>
<td>M. Menozzi Jäckli, R. Huang, M. Siegrist</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td>Strategies of human-system-interaction, individual needs, physical &amp; mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance. The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.</td>
</tr>
<tr>
<td>376-1179-00L</td>
<td>Applications of Cybernetics in Ergonomics</td>
<td>1</td>
<td>M. Menozzi Jäckli, Y.-Hedinger Huang, R. Huang</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td>Cybernetics systems have been studied and applied in various research fields, such as for applications in ergonomics. Topics discussed in this lecture (man-machine-interaction, performance in multi-modal interactions, quantification in gestalt principles for the use in product development, information processing) are deepened with exercises conducted at our labs. To learn and practice cybernetics principles in interface designs and product development.</td>
</tr>
<tr>
<td>376-1219-00L</td>
<td>Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions</td>
<td>3</td>
<td>R. Riener, O. Lambercy</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td>Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system. Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution. This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.</td>
</tr>
</tbody>
</table>

Content

Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
- Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

Literature

Introductory Books:


Selected Journal Articles and Web Links:

Prerequisites / notice

Target Group:
Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
Students of other departments, faculties, courses are also welcome
This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

376-1351-00L Micro/Nanotechnology and Microfluidics for W 2 credits 2V E. Delamarche

### Biomedical Applications

**Abstract**

This course is an introduction to techniques in micro/nanotechnology and to microfluidics. It reviews how many familiar devices are built and can be used for research and biomedical applications. Transistors for DNA sequencing, beamers for patterning proteins, hard-disc technology for biosensing and microfluidics for point-of-care diagnostics are just a few examples of the covered topics.

**Objective**

The main objective of the course is to introduce micro/nanotechnology and microfluidics to students having any technical background. The course is multi-disciplinary and covers a broad range of techniques. For each lecture, a historical perspective is given to illustrate by whom and how the techniques were invented.

The course should familiarize the students with the techniques used in micro/nanotechnology, cleanroom microfabrication, and show them how micro/nanotechnology pervades throughout life sciences. Microfluidics will be emphasized due to their increasing importance in research and for medical applications.

The second objective is to have life sciences students less intimidated by micro/nanotechnology and make them able to link instruments and techniques to specific problems that they might have in their projects/studies. This will also help students getting access to the ETHZ/IBM Nanotech Center infrastructure if needed.

**Content**

Mostly formal lectures (2 x 45 min), with a 2 hour visit of the Binnig and Rohrer Nanotechnology Center (Rueschlikon) and introduction to cleanroom and micro/nanotechnology instruments, last 3 weeks would be dedicated to the presentation and evaluation of projects by students (2 to 3 students per team). For this, about 10 recent technologies are listed and each team picks a technology and makes a short report and presentation describing how it works, its strengths and weaknesses, and describes what problem it solves.

In terms of technical content, the lectures will cover:
- an overview of the microelectronics industry, Moore’s law, field-effect transistors, next-generation DNA sequencing
- liquid crystal displays, organic light emitting diodes, electrophoretic displays, microrobots and beamers, photopatterning of proteins and cells, optogenetics, and flexible displays and electronics
- hard disk drives and the giant magnetoresistance effect, magnetic nanoparticles, photonics, magnetic sensing and optical biosensing
- cleanroom techniques and instruments, from design to microfabrication of simple devices and microfluidics, examples of DNA microarrays
- the principles of microfluidics, microfluidic functions and fabrication, from microfluidics for research to point-of-care diagnostics, and the (infamous) history of Theranos, as well as some discussions on diagnostics for COVID, R0, and (im)precision of diagnostic devices and why it matters
- hobby electronics, making a device for 10$ and controlling it using a smartphone.

**Prerequisites / notice**

The nanotech center and labs visit at IBM would be mandatory, as well as attending the student project presentations.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1353-00L</td>
<td>Nanostructured Materials Safety</td>
<td>W 2</td>
<td>P. Wick</td>
</tr>
<tr>
<td>376-1504-00L</td>
<td>Physical Human Robot Interaction (pHRI)</td>
<td>W 4</td>
<td>O. Lambercy</td>
</tr>
</tbody>
</table>

**Objective**

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and de-sign safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;  
2) compare and select mechatronic components that optimally fulfill the defined design requirements;  
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;  
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;  
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;  
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

**Content**

This course offers an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

**Lecture notes**

Will be distributed on Moodle before the lectures.


Prerequisites / notice
Notice:
The registration is limited to 26 students
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous classes.
http://www.relab.ethz.ch/education/courses/phri.html

Prerequisites / notice
A Windows laptop (or Windows on Mac) is required for certain of the lab modules.

Prerequisites / notice
Notice:
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Lecture notes
Handouts are deposited online (moodle).
Biomedical datasets are increasing in size and complexity, and discoveries arising from their analysis have important implications in human health and biotechnological advances. While the potential of biomedical dataset analysis is considerable, preclinical researchers often lack the computational tools to analyze them. This course will provide the basis of data analysis of large biomedical data.

**Objective**

This course aims to provide practical tools to analyze large biomedical datasets, and it is tailored towards experimental researchers in the life sciences with minimal prior programming experience, but with a strong interest in exploring big data to solve own research problems. Through theoretical classes, practical demonstrations, in class exercises and homework, the participants will master computational approaches for big data analysis. The course will cover:

- Basis of Python programming and UNIX;
- High performance computing;
- Manipulation and cleaning of large datasets with Pandas;
- Visualization tools (Matplotlib, Seaborn);
- Machine learning and numerical libraries (SciPy, NumPy, Statsmodels, Scikit-Learn);
- Statistical analysis and modeling of big data, and applications to biomedical datasets (statistical learning, distributions, linear and logistic regressions, principal component analysis, clustering, classification, time series analysis, tree-based methods, predictive models).

**Prerequisites / notice**

Basic understanding of mathematics and statistics, as taught in basic courses at the Bachelor’s level.

**Content**

While learning the programming skills needed to manipulate and visualize the data, participants will learn the statistical and modeling approaches for big data analysis. The course will cover:

-0629-00L  Applied Biostatistics  W 4 credits  3G  M. Tanadini

This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.

**Objective**

After this course students:

- got introduced to Linear Mixed-Effects Models
- got introduced to Generalised Additive Models
- are able to use R and R packages to solve an applied problem in Biostatistics
- can perform the data analysis using the statistical software R
- can interpret the results of such an analysis and draw valid "biological" conclusions
This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts. The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommended to view the online R course "etuoR".

Content

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, scanning probe and diffraction techniques allowing studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

Prerequisites / notice

Physics in Medical Research: From Atoms to Cells

402-0674-00L

Abstract

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocye behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

Domain B - Method-specific Competencies

- Adaptable and Flexible
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Domain C - Social Competencies

- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies

- 1.5V
- W
- 6 credits
- 2V+1U
- B. K. R. Müller

535-0423-00L

Drug Delivery and Drug Targeting

The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

Objective

The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

Content

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

Lecture notes

Selected lecture notes, and supporting material will be directly provided or may be downloaded from the course website.

Literature


Further references will be provided in the course.

551-0317-00L

Immunology I

W

3 credits

2V

M. Kopf, A. Oxenius
Introduction into structural and functional aspects of the immune system. 
Basic knowledge of the mechanisms and the regulation of an immune response. 

- Introduction and historical background 
- Innate and adaptive immunity. Cells and organs of the immune system 
- B cells and antibodies 
- Generation of diversity 
- Antigen presentation and Major Histocompatibility (MHC) antigens 
- Thymus and T cell selection 
- Autoimmunity 
- Cytotoxic T cells and NK cells 
- T1 and Th2 cells, regulatory T cells 
- Allergies 
- Hypersensitivities 
- Vaccines, immune-therapeutic interventions 

Introduction into structural and functional aspects of the immune system. 
Basic knowledge of the mechanisms and the regulation of an immune response. 

Cellular Biochemistry (Part I) 

Lecture notes 
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien". 

Prerequisites / notice 
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Taught competencies 

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

Domain B - Method-specific Competencies 
Analytical Competencies 
Decision-making 
Media and Digital Technologies 
Problem-solving 

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

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

Cellular Biochemistry (Part I) 

W 3 credits 2V 4 credits 

551-0319-00L 

Biological Engineering and Biotechnology 

W 4 credits 3V 6 credits 

636-0108-00L 

Abstract 

Introduction into structural and functional aspects of the immune system. 
Basic knowledge of the mechanisms and the regulation of an immune response. 

Abstract 

Introduction into structural and functional aspects of the immune system. 
Basic knowledge of the mechanisms and the regulation of an immune response. 

Objective 
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer. 

Content 

Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.
Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes 
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.bioc.ethz.ch)

Literature 
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice 
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.
Abstract
A "cook-and-look" approach to process design is no longer applicable in the current environmental, nutritional and competitive constraints.

Objective
The objective of this course is to highlight the intimate links between human physiology and product sensory and nutritional functions. To optimize these functions, an understanding of the physiological functions that interact and encode the actions of those product structures must be well understood.

Therefore the objective of this course is for students to be equipped with a skill set that will encompass basic digestion and sensory physiology knowledge and food structures.

The students will be exposed to this interplay all along the GI tract, including taste, aroma and texture perception, swallowing mechanics and gastro intestinal digestion with an engineering or physical sciences angle.
Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content

- Basics of theory of probability
- Boltzmann’s law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o’clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature


Prerequisites / notice

- Differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton’s and Coulomb’s laws (basics of Mechanics and Electrostatics).

Notions of vectors in 2D and 3D are beneficial.

327-2125-00L Microscopy Training SEM I - Introduction to SEM

W 2 credits 3P


Abstract

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

Autumn Semester 2021


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Objective
- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content
During the course, students learn through lectures, demonstrations, and hands-on sessions how to set up and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Prerequisites / notice
No mandatory prerequisites.

Lecture notes
Lecture notes will be distributed.

Literature
- R. Müller
- A. Sologubenko, M. Willinger

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Prerequisites / notice
No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.
### Objective
1. Understanding and practical implementation of biosignal processes methods for imaging
2. Understanding of imaging techniques including radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging
3. Knowledge of computing, programming, modelling and simulation fundamentals
4. Computational and systems thinking as well as scripting and programming skills
5. Understanding and practical implementation of emerging computational methods and their application in medicine including artificial intelligence, deep learning, big data, and complexity
6. Understanding of the emerging concept of personalized and in silico medicine
7. Encouragement of critical thinking and creating an environment for independent and self-directed studying

### Content
Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine. For the imaging portion of the course, biosignal processing, radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging are covered. For the computing portion of the course, computing, programming, and modelling and simulation fundamentals are covered as well as their application in artificial intelligence and deep learning; complexity and systems medicine; big data and personalised medicine; and computational physiology and in silico medicine.

The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup: in the first part (TORQUEs: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A). Following the Q&A, the students will form small groups to acquire additional knowledge using online, python-based activities via JupyterHub or additionally distributed material and discuss their findings in teams. Learning outcomes will be reinforced with weekly Moodle assignments, to be completed during the flipped classroom portion.

### Lecture notes
- Stored on Moodle.
- Lectures will be given in English.

### Prerequisites
- Notice

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Notice</th>
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<td>Prerequisites /</td>
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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Week</th>
<th>Credits</th>
<th>Grouping</th>
<th>Lecturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0208-00L</td>
<td>Molecular and Cellular Biology of Exercise and Muscle Regeneration - Practical Aspects</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>O. Bar-Nur, K. De Bock</td>
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<tr>
<td></td>
<td>Prerequisites: Advanced Physiology and Pathophysiology (376-0008-00L)</td>
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<td></td>
<td>Laboratory Course in Molecular Biology (376-0006-02L)</td>
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<tr>
<td>Abstract</td>
<td>The skeletal muscle biology field purposes to understand how muscles coordinate movement, regenerate following injury and adapt to exercise stimuli. In this course, the students will acquire insights into the molecular aspects of muscle biology and exercise, in addition to gaining hands-on experience in experimental techniques that are commonly used to research muscle regeneration and exercise.</td>
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<tr>
<td>Objective</td>
<td>The objective of this course is to introduce students into current research topics and outstanding questions in skeletal muscle biology. Also, the course will give students hands-on experience in respect to the tools needed to perform basic molecular biology research in the field of exercise and skeletal muscle biology. Students will learn how to translate a scientific question in muscle biology into a small scientific project. They will learn how to design an experiment and to analyze and critically interpret experimental data.</td>
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<tr>
<td>Content</td>
<td>The course will consist of 4 main research themes and the anticipated 16 students will be divided into 4 subgroups of 4 students- each one will focus on one of the following research topics:</td>
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<tr>
<td></td>
<td>Topic 1: Molecular pathways that control muscle stem cell self-renewal and differentiation</td>
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<td></td>
<td>Topic 2: Genome engineering to correct genetic mutations that cause muscle diseases</td>
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<td>Topic 3: Muscle fiber composition, force production and insulin sensitivity</td>
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<td></td>
<td>Topic 4: Amino acid sensitivity in skeletal muscle following exercise</td>
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<td>The course will be organized into 7 sessions, each approx. 4 hours: the first 2 sessions will be theoretical and include an introductory lectures by the professors in addition to a journal club presentation by the students. This journal club aims to provide theoretical and scientific background that will be used to identify outstanding research questions. This will be followed by 4 practical sessions (hands-on experience) and 1 final evaluation session. For the journal club, each group of students will receive a peer-review article that is highly relevant to the respective group’s research topic. Each of the 4 groups will present and discuss the article in a journal club format to the rest of the participants the following week. During the four practical sessions, students will gain hands-on experiences and learn different lab techniques related to molecular biology of exercise and muscle regeneration. Each group will be presented with a research objective that is related to their topic, and perform in collaboration with teaching assistants a set of experiments that aim to address the research objective. At the final evaluation session, each group of students will present their results and identify follow-up research questions and hypothesis based on their experimental achievements.</td>
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Select practical methods that the proposed course will teach include:

i. Group 1: tissue culture, isolation of muscle stem cells via FACSC, differentiation of muscle stem cells into muscle fibers, small molecules screens, quantitative analysis of muscle cell proliferation and fusion, immunofluorescence.

ii. Group 2: tissue culture, differentiation of muscle stem cells into muscle fibers, guide RNA design and Crispr-Cas9 gene editing of genetic mutations that cause muscle diseases in muscle stem cells and fibers, Immunofluorescence and PCR.

iii. Group 3: ex vivo assessment of muscle force characteristics, cryosectioning of muscle tissue, immunofluorescence and western blot.

iv. Group 4: tissue culture of muscle stem cells, isolation of muscle stem cells and differentiation into muscle fibers, amino acid stimulation of muscle fibers, Western blot.

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<tr>
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<th>Credits</th>
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<th>Lecturer(s)</th>
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<tbody>
<tr>
<td>376-0303-00L</td>
<td>Colloquium in Translational Science (Autumn Semester)</td>
<td></td>
<td>1 credit</td>
<td>1K</td>
<td>M. Ristow, A. Alimonti, N. Cesarovic, C. Ewald, V. Falk, J. Goldhahn, K. Maniura, R. M. Rossi, S. Schürle-Finke, G. Shivashankar, E. Yavaya, V. Vogel</td>
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<tr>
<td></td>
<td>Prerequisites: 376-0008-00L Advanced Physiology and Pathophysiology</td>
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<td></td>
<td>376-0006-02L Laboratory Course in Molecular biology</td>
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<tr>
<td>Abstract</td>
<td>Current topics in translational medicine presented by speakers from academia and industry.</td>
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<tr>
<td>Objective</td>
<td>Getting insight into actual areas and problems of translational medicine.</td>
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<tr>
<td>Content</td>
<td>Timely and concise presentations of postgraduate students, post-docs, senior scientists, professors, as well as external guests from both academics and industry will present topics of their interest related to translational medicine.</td>
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<th>Course Code</th>
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<th>Credits</th>
<th>Grouping</th>
<th>Lecturer(s)</th>
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<tbody>
<tr>
<td>376-1151-00L</td>
<td>Translation of Basic Research Findings from Genetics and Molecular Mechanisms of Aging</td>
<td></td>
<td>3 credits</td>
<td>2V</td>
<td>to be announced</td>
</tr>
</tbody>
</table>

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Recently, several start-up companies are aiming to translate basic molecular findings into new drugs/therapeutic interventions to slow aging or post-pone age-related diseases (e.g., Google founded Calico or Craig Venter's Human Longevity, Inc.). This course will teach students the basic skill sets to formulate their own ideas, design experiments to test them and explains the next steps to translate recent discoveries into new therapeutic interventions.

**Learning objectives include:**
1. Evaluate the current problem of our aging population, the impact of age-dependent diseases and current strategies to prevent these age-dependent diseases.
2. Analyze/compare current molecular/genetic strategies that address these aging problems.
3. Analyze case studies about biotech companies in the aging sector. Apply the scientific methods to formulate basic research questions to address these problems.
4. Generate own hypotheses (educated guess/idea), design experiments to test them, and map out the next steps to translate them.

**Content**
Overview of aging and age-related diseases. Key discoveries in molecular biology of aging. Case studies of biotech companies addressing age-related complications. Brief introduction from bench to bedside with focus on start-up companies.

**Prerequisites / notice**
No compulsory prerequisites, but student should have basic knowledge about genetics and molecular biology.
**Immunology I and II recommended but not compulsory**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Instructor(s)</th>
<th>Prerequisites / notice</th>
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<tr>
<td>551-0309-00L</td>
<td>Concepts in Modern Genetics</td>
<td>W 6</td>
<td>4V</td>
<td>Y. Barral, D. Bopp, A. Hajnal, O. Voinnet</td>
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<td></td>
<td><em>Information for UZH students:</em> Enrolment to this course unit only possible at ETH. No enrolment to module BIOL348 at UZH. Please mind the ETH enrolment deadlines for UZH students: <a href="https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html">https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html</a>*</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<tr>
<td></td>
<td>Objective</td>
<td>This course focuses on the concepts of classical and modern genetics and genomics.</td>
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<tr>
<td></td>
<td>Content</td>
<td>The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.</td>
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<td></td>
<td>Lecture notes</td>
<td>Scripts and additional material will be provided during the semester.</td>
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<tr>
<td>551-0317-00L</td>
<td>Immunology I</td>
<td>W 3</td>
<td>2V</td>
<td>M. Kopf, A. Oxenius</td>
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<tr>
<td></td>
<td><em>Abstract</em></td>
<td>Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.</td>
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<tr>
<td></td>
<td><em>Objective</em></td>
<td>Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.</td>
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<td></td>
<td><em>Content</em></td>
<td>- Introduction and historical background - Innate and adaptive immunity. Cells and organs of the immune system - B cells and antibodies - Generation of diversity - Antigen presentation and Major Histoincompatibility (MHC) antigens - Thymus and T cell selection - Autoimmunity - Cytotoxic T cells and NK cells - Th1 and Th2 cells, regulatory T cells - Allergies - Hypersensitivities - Vaccines, immune-therapeutic interventions</td>
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<td></td>
<td><em>Lecture notes</em></td>
<td>Electronic access to the documentation will be provided. The link can be found at &quot;Lernmaterialien&quot;</td>
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<td><em>Prerequisites / notice</em></td>
<td>For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a &quot;Sessionsprüfung&quot;. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.</td>
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<td></td>
<td><em>Taught competencies</em></td>
<td>Domain A - Subject-specific Competencies</td>
<td>assessed</td>
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<td>Domain B - Method-specific Competencies</td>
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<td>Domain C - Social Competencies</td>
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<td>Domain D - Personal Competencies</td>
<td>assessed</td>
<td>assessed</td>
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<tr>
<td>551-0512-00L</td>
<td>Current Topics in Molecular and Cellular Neurobiology</td>
<td>W 2</td>
<td>1S</td>
<td>U. Suter</td>
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<tr>
<td></td>
<td><em>Abstract</em></td>
<td>Does not take place this semester. Number of participants limited to 8.</td>
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<td></td>
<td><em>Objective</em></td>
<td>The course is a literature seminar or &quot;journal club&quot;. Each Friday a student, or a member of the Suter Lab in the Institute of Molecular Health Sciences, will present a paper from the recent literature.</td>
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<td><em>Content</em></td>
<td>You will present one paper yourself. Give an introduction to the field of the paper, then show and comment on the main results (all the papers we present are available online, so you can show original figures with a beamer). Finish with a summary of the main points and a discussion of their significance. You are expected to take part in the discussion and to ask questions. To prepare for this you should read all the papers beforehand (they will be announced a week in advance of the presentation).</td>
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<td></td>
<td><em>Lecture notes</em></td>
<td>Presentations will be made available after the seminars.</td>
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</tbody>
</table>
**551-0571-00L** From DNA to Diversity (University of Zurich)  
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.  
UZH Module Code: BIO336  
Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmossl/en/studies/application/deadlines.html  
**Abstract**  
The evolution of the various body-plans is investigated by means of comparison of developmentally essential control genes of molecularly analysed model organisms.  
**Objective**  
By the end of this module, each student should be able to  
- recognize the universal principles underlying the development of different animal body plans.  
- explain how the genes encoding the molecular toolkit have evolved to create animal diversity.  
- relate changes in gene structure or function to evolutionary changes in animal development.  
Key skills:  
- By the end of this module, each student should be able to  
  - present and discuss a relevant evolutionary topic in an oral presentation  
  - select and integrate key concepts in animal evolution from primary literature  
  - participate in discussions on topics presented by others  

**551-1153-00L** Systems Biology of Metabolism  
**Number of participants limited to 15.**  
**Abstract**  
Starting from contemporary biological problems related to metabolism, the course focuses on systems biological approaches to address them. In a problem-oriented, this-is-how-it-is-done manner, we thereby teach modern methods and concepts.  
**Objective**  
Develop a deeper understanding of how relevant biological problems can be solved, thereby providing advanced insights to key experimental and computational methods in systems biology.  
**Content**  
The course will be given as a mixture of lectures, studies of original research and guided discussions that focus on current research topics. For each particular problem studied, we will work out how the various methods work and what their capabilities/limits are. The problem areas range from microbial metabolism to cancer cell metabolism and from metabolic networks to regulation in populations and single cells. Key methods to be covered are various modeling approaches, metabolic flux analyses, metabolomics and other omics.  
**Lecture notes**  
Script and original publications will be supplied during the course.  
**Prerequisites / notice**  
The course extends many of the generally introduced concepts and methods of the Concept Course in Systems Biology. It requires a good knowledge of biochemistry and basics of mathematics and chemistry.  

**551-1171-00L** Immunology: From Milestones to Current Topics  
**W** 4 credits  
**2S**  
U. Sauer, N. Zamboni, M. Zampieri  
**Abstract**  
We will focus on the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.  
**Objective**  
The course will cover the current grand topics in immunology: B cells, innate immunity, antigen presentation, tumor immunity, T cells, myeloid cells and stromal cells. For each topic two or four hours will be allocated. Historical milestone papers will be presented by the tutor/lecturer providing an overview on the development of the theoretical framework and critical technological advances. The students will read the historical milestone papers and contribute to the discussion. In the second part of the lecture, students will present recent high impact research papers that have emerged from the landmark achievements of the previously discussed milestone concepts.  
**Content**  
Milestones and current topics of innate immunity, antigen presenting, B cells, thymus and T cells, cytotoxic T cells, NK cells, stromal cells, CNS immunity and tumor immunology.  
**Lecture notes**  
Original and review articles will be distributed by the respective lecturer.  
**Literature**  
Lekturerunterlagen werden vor Beginn des Kurses auf folgender website zugänglich sein: https://moodle-app2.let.ethz.ch/course/view.php?id=15568  

**551-1303-00L** Cellular Biochemistry of Health and Disease  
**W** 4 credits  
**2S**  
V. Korkhov, T. Ishikawa, M. Jagannathan, R. Kroschewski, G. Neurohr, M. Peter, A. E. Smith, B. Snijder, K. Weis  
**Abstract**  
During this Masters level seminar style course, students will explore current research topics in cellular biochemistry focused on the structure, function and regulation of selected cell components, and the consequences of dysregulation for pathologies.  
**Objective**  
Students will work with experts toward a critical analysis of cutting-edge research in the domain of cellular biochemistry, with emphasis on normal cellular processes and the consequences of their dysregulation. At the end of the course, students will be able to introduce, present, evaluate, critically discuss and write about recent scientific articles in the research area of cellular biochemistry.  
**Content**  
Guided by an expert in the field, students will engage in classical round-table style discussions of current literature with occasional frontal presentations. Students will alternate as discussion leaders throughout the semester, with the student leader responsible to briefly summarize key general knowledge and context of the assigned primary research paper. Together with the faculty expert, all students will participate in discussion of the primary paper, including the foundation of the biological question, specific questions addressed, key methods, key results, remaining gaps and research implications.  
**Literature**  
The literature will be provided during the course  
**Prerequisites / notice**  
The course will be taught in English.  

**636-0017-00L** Computational Biology  
**W** 6 credits  
**3G+2A**  
T. Vaughan
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:
- epidemiology
- pathogen evolution
- macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Handouts during course
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Lecture notes
Handout during the course.

This project takes place between end of Spring Semester and beginning of Autumn Semester. Registration in April. Please note that the number of ECTS credits and the actual work load are disconnected.

701-1703-00L Evolutionary Medicine for Infectious Diseases

W 3 credits

A. Hall

Number of participants limited to 35.

Waiting list will be deleted October 3rd, 2021.

This course explores infectious disease from both the host and pathogen perspective. Through short lectures, reading and active discussion, students will identify areas where evolutionary thinking can improve our understanding of infectious diseases and, ultimately, our ability to treat them effectively.
<table>
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<th>Course Code</th>
<th>Course Title</th>
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<th>Authors</th>
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</thead>
<tbody>
<tr>
<td>752-3105-00L</td>
<td>Analytical Competencies</td>
<td>W</td>
<td>3</td>
<td>E. J. Windhab, M. Devzeaux de Laverne, S. Michlig Gonzalez, T. Wooster</td>
</tr>
</tbody>
</table>

**Objective**

Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanic informatics, with particular emphasis on bacteria and viruses.

**Content**

We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (~20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

**Literature**

The focus is on primary literature, but for some parts the following text books provide good background information:

- Schmid Hempel 2011 Evolutionary Parasitology
- Stearns & Medzhitov 2016 Evolutionary Medicine

**Prerequisites / notice**

A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.

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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-4009-00L</td>
<td>Physiology Guided Food Structure and Process Design</td>
<td>W</td>
<td>3</td>
<td>M. Loesener, M. Schmelcher, M. Schuppler, E. Wetter Slack</td>
</tr>
</tbody>
</table>

**Objective**

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

**Content**

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Literature**

Recommendations will be given in the first lecture

**Prerequisites / notice**

Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break !

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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-6101-00L</td>
<td>Molecular Biology of Foodborne Pathogens</td>
<td>W</td>
<td>3</td>
<td>M. B. Zimmermann</td>
</tr>
</tbody>
</table>

**Objective**

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**

There is no script; PowerPoint presentations will be made available on-line to students.

**Literature**

To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-6105-00L</td>
<td>Epidemiology and Prevention</td>
<td>W</td>
<td>3</td>
<td>M. Puhan, R. Heusser</td>
</tr>
</tbody>
</table>

**Objective**

The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Content**

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

**Taught competencies**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Analytical Competencies: assessed
  - Decision-making: assessed

- **Domain B - Method-specific Competencies**
  - Problem-solving: not assessed
  - Project Management: not assessed
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed

- **Domain C - Social Competencies**
  - Creative Thinking: not assessed
  - Critical Thinking: assessed
### Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0300-00L</td>
<td>Translational Science for Health and Medicine</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>J. Goldhahn, C. Wolfrum</td>
</tr>
</tbody>
</table>

**Abstract**

Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

**Objective**

After completing this course, students will be able to understand:

- Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)
- Basics about incidence, prevalence etc., and orphan indications
- How to choose the appropriate research type and methodology
- Ethical considerations including ethics application
- Pros and cons of different types of research
- Coordination of complex approaches incl. timing and resources
- How to measure success?
- Outcome variables
- Improving the translational process
- Challenges of communication?
- How independent is translational science?
- Academic boundary conditions vs. industrial influences

**Content**

- What is translational science and what is it not?
- Disease concepts and consequences for research
- How to identify need?
- How to choose the appropriate research type and methodology
- Ethical considerations including ethics application
- Pros and cons of different types of research
- Coordination of complex approaches incl. timing and resources
- How to measure success?
- Outcome variables
- Improving the translational process
- Challenges of communication?
- How independent is translational science?
- Academic boundary conditions vs. industrial influences

Positive and negative examples will be illustrated by distinguished guest speakers.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-0302-01L</td>
<td>GCP Basic Course (Modules 1 and 2)</td>
<td>O</td>
<td>1</td>
<td>1G</td>
<td>G. Senti</td>
</tr>
</tbody>
</table>

**Abstract**

The basic course in “Good Clinical Practice” (GCP) contains of two full-time training days (Module 1 and Module 2) and addresses elementary aspects for the appropriate conduct of clinical trials and non-clinical research projects involving human beings. Successful participation will be confirmed by a certificate that is recognized by the Swiss authorities.

**Objective**

Students will get familiar with:

- Key Ethics documents
- (Inter)national Guidelines and Laws (e.g. ICH-GCP, DIN EN ISO 14155, TPA, HRA)
- Sequence of research projects and project-involved parties
- Planning of research projects (statistics, resources, study design, set-up of the study protocol)
- Approval of research projects by Authorities (SwissEthics, Swissmedic, FOPH)
- Roles and responsibilities of project-involved parties

Students will learn how to:

- Classify research projects according the risk-based approach of the HRA
- Write a study protocol
- Inform participating patients/study subjects
- Obtain consent by participating patients/study subjects
- Classify, document and report Adverse Events
- Handle projects with biological material from humans and/or health-related personal data

**Content**

Module 1:

- Research and Research Ethics, Guidelines, (inter)national Legislation, Development of therapeutic products, Methodology (Study Design), Study documents (Protocol, Investigator's Brochure, Patient Information Leaflet, Informed Consent Form)

Module 2:

- Roles and Responsibilities, Approval procedures, Notification and Reporting, Study documentation, Research with biological material and health-related data, data protection, data retention

### Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1305-00L</td>
<td>Development of the Nervous System (University of Zurich)</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: BIO344*

**Abstract**

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

**Objective**

On successful completion of the module the student should be able to

- relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system
- identify key steps in development underlying neurological syndromes and diseases

**Key skills**

On successful completion of the module the student should be able to

- interpret and critically evaluate original research reports
- apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

**Content**

The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.
Lecture notes
Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/ as BIOC44

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

Prerequisites / notice
Auxiliary tools:
None. Bring something to write and your student ID

<table>
<thead>
<tr>
<th>376-1305-01L</th>
<th>Neural Systems for Sensory, Motor and Higher Brain Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>3 credits</td>
</tr>
<tr>
<td>Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIOC343 at UZH. Please mind the ETH enrolment deadlines for UZH students: <a href="https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html">https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html</a></td>
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</tbody>
</table>

Abstract
The course covers the structure, plasticity and regeneration of the adult nervous system (NS) with focus on: sensory systems, cognitive functions, learning and memory, molecular and cellular mechanisms, animal models, and diseases of the NS.

Objective
The aim is to give a deepened insight into the structure, plasticity and regeneration of the nervous system based on molecular, cellular and biochemical approaches.

Content
The main focus is on the structure, plasticity and regeneration of the NS: biology of the adult nervous system; structural plasticity of the adult nervous system, regeneration and repair; networks and nerve fibers, regeneration, pathological loss of cells.

Literature
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle / OLAT.

<table>
<thead>
<tr>
<th>551-0309-00L</th>
<th>Concepts in Modern Genetics</th>
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</thead>
<tbody>
<tr>
<td>W</td>
<td>6 credits</td>
</tr>
<tr>
<td>Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIOC44 at UZH. Please mind the ETH enrolment deadlines for UZH students: <a href="https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html">https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html</a></td>
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</table>

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA-repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

<table>
<thead>
<tr>
<th>227-0047-00L</th>
<th>Image Analysis and Computer Vision</th>
</tr>
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<tbody>
<tr>
<td>W</td>
<td>6 credits</td>
</tr>
<tr>
<td>Objective: Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.</td>
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<tr>
<td>Content: This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.</td>
<td></td>
</tr>
<tr>
<td>Lecture notes: Course material Script, computer demonstrations, exercises and problem solutions</td>
<td></td>
</tr>
<tr>
<td>Prerequisites: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.</td>
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<table>
<thead>
<tr>
<th>227-1037-00L</th>
<th>Introduction to Neuroinformatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>6 credits</td>
</tr>
<tr>
<td>Abstract: The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are preordained.</td>
<td></td>
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<tr>
<td>Objective: Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this main 21st century problem and how each discipline can contribute to discovering solutions.</td>
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</table>
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>V</th>
<th>Author</th>
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</thead>
<tbody>
<tr>
<td>227-1047-00L</td>
<td>Consciousness: From Philosophy to Neuroscience (University of Zurich)</td>
<td>3</td>
<td>2V</td>
<td>D. Kiper</td>
</tr>
<tr>
<td>327-2125-00L</td>
<td>Microscopy Training SEM I - Introduction to SEM</td>
<td>2</td>
<td>3P</td>
<td>P. Zeng, A. G. Bittermann, S. Gerstl, L. Graufilia Morales, K. Kunze, J. Reuteler</td>
</tr>
<tr>
<td>327-2126-00L</td>
<td>Microscopy Training TEM I - Introduction to TEM</td>
<td>2</td>
<td>3P</td>
<td>P. Zeng, E. J. Barthazy Meier, A. G. Bittermann, F. Gramm, A. Sologubenko, M. Willinger</td>
</tr>
</tbody>
</table>

**Lecture notes**

None

**Literature**

- Practice on real-world samples and report results
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities

**Prerequisites / notice**

Since we are all experts on consciousness, we expect active participation and discussions! No mandatory prerequisites.

**Abstract**

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

**Objective**

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

**Content**

During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

**Lectures:**

- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

**Practicals:**

- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

**Lecture notes**

Lecture notes will be distributed.

**Literature**


**Data:** 14.12.2021 12:41
For PhD students, postdocs and others, a fee will be charged (http://www.scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: (link will follow)

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

Content
Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

Prerequisites / notice
No compulsory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

Literature

Abstract
This course provides hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (nerve/brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students read scientific material, set up experiments, perform measurements in the lab, analyse data, apply statistics and write short reports or essays.

Objective
This course will prepare students for experimental work as it is typically done during the master thesis. The goal is to gain hands-on experience with measurement and analysis methods relevant for Humans Systems Neuroscience and Motor control (for example peripheral nerve stimulation, electrical and magnetic brain stimulation, EMG, EEG, psycho-physical paradigms etc). Students will learn how to perform small scientific projects in this area. Students will work individually or in small groups and solve scientific problems which require them to perform measurements in human participants, extract relevant readouts from the data, apply appropriate statistics and interpret the results. They will also be required to write small essays and reports and they will get feedback on their writing throughout the course.

Prerequisites / notice
No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

Abstract
Recently, several start-up companies are aiming to translate basic molecular findings into new drugs/therapeutic interventions to slow aging or post-pone age-related diseases (e.g., Google founded Calico or Craig Venter's Human Longevity, Inc.). This course will teach students the basic skill sets to formulate their own ideas, design experiments to test them and explains the next steps to translating them into a successful drug/therapeutic intervention.

Objective
The overall goal of this course is to be able to analyse current therapeutic interventions to identify an unmet need in molecular biology of aging and apply scientific thinking to discover new mechanisms that could be used as a novel therapeutic intervention.

Learning objectives include:
1. Evaluate the current problem of our aging population, the impact of age-dependent diseases and current strategies to prevent these age-dependent diseases
2. Analyse/compare current molecular/genetic strategies that address these aging problems
3. Analyse case studies about biotech companies in the aging sector. Apply the scientific methods to formulate basic research questions to address these problems.
4. Generate own hypotheses (educated guess/idea), design experiments to test them, and map out the next steps to translate them.

Content
Overview of aging and age-related diseases. Key discoveries in molecular biology of aging. Case studies of biotech companies addressing age-related complications. Brief introduction from bench to bedside with focus on start-up companies.

Prerequisites / notice
No compulsory prerequisites, but student should have basic knowledge about genetics and molecular biology.

Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.
### 376-1179-00L Applications of Cybernetics in Ergonomics

**Objective**
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in microscopic factors such as the behavior of consumers and objectives of economy.

**Content**
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among environments, consumers, behavior, and tasks

**Literature**
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

### 376-1414-00L Current Topics in Brain Research (HS)

**Objective**
To exchange scientific knowledge and data and to promote communication and collaborations among researchers. For students: Critical discussion of current research. Students aiming at getting a credit point for this colloquium choose one topic and write a critical essay on the presented research topic.

**Content**
- Different scientific guests working in the field of molecular cognition, neurochemistry, neuromorphology and neurophysiology present their latest scientific results.

**Lecture notes**
no handout

**Literature**
- Literature will be distributed on Moodle before the lectures.

**Prerequisites / notice**
- Some of the seminars will be shared with the Institute of Neuroinformatics (INI) of UZH.

### 376-1504-00L Physical Human Robot Interaction (pHRI)

**Objective**
The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechachronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1. Identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2. Compare and select mechatronic components that optimally fulfill the defined design requirements;
3. Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4. Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5. Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6. Investigate and optimize one aspect of the physical setup and convey the gained insights in a technical presentation.

**Content**
This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

**Lecture notes**
Will be distributed on Moodle before the lectures.
Introduction into structural and functional aspects of the immune system.

Biomedical datasets are increasing in size and complexity, and discoveries arising from their analysis have important implications in human health and biotechnological advances. While the potential of biomedical dataset analysis is considerable, preclinical researchers often lack the computational tools to analyze them. This course will provide the basis of data analysis of large biomedical data problem of their choosing and using publicly available population-based biomedical datasets.

The students are expected to have basic control knowledge from previous classes.

The registration is limited to 26 students.

Notice:
- The registration is limited to 26 students.
- There are 4 credit points for this lecture.
- The lecture will be held in English.
- The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html

Prerequisites / notice

Big Data Analysis in Biomedical Research

Biomedical datasets are increasing in size and complexity, and discoveries arising from their analysis have important implications in human health and biotechnological advances. While the potential of biomedical dataset analysis is considerable, preclinical researchers often lack the computational tools to analyze them. This course will provide the basis of data analysis of large biomedical data

This course aims to provide practical tools to analyze large biomedical datasets, and it is tailored towards experimental researchers in the life sciences with minimal prior programming experience, but with a strong interest in exploring big data to solve own research problems. Through theoretical classes, practical demonstrations, in class exercises and homework, the participants will master computational methods to independently manipulate large datasets, effectively visualize big data, and analyze it with appropriate statistical tools and machine learning approaches. For the final assessment, students will conduct an independent data analysis project based on a biomedical problem of their choosing and using publicly available population-based biomedical datasets.

While learning the programming skills needed to manipulate and visualize the data, participants will learn the statistical and modeling approaches for big data analysis. The course will cover:
- Basis of Python programming and UNIX;
- High performance computing;
- Manipulation and cleaning of large datasets with Pandas;
- Visualization tools (Matplotlib, Seaborn);
- Machine learning and numerical libraries (SciPy, NumPy, Statsmodels, Scikit-Learn);
- Statistical analysis and modeling of big data, and applications to biomedical datasets (statistical learning, distributions, linear and logistic regressions, principal component analysis, clustering, classification, time series analysis, tree-based methods, predictive models).

Basic understanding of mathematics and statistics, as taught in basic courses at the Bachelor’s level.

Prerequisites / notice

Immunology I

Introduction into structural and functional aspects of the immune system.

Basic knowledge of the mechanisms and the regulation of an immune response.

Introduction into structural and functional aspects of the immune system.

Basic knowledge of the mechanisms and the regulation of an immune response.

- Introduction to background
  - Innate and adaptive immunity, Cells and organs of the immune system
  - B cells and antibodies
  - Generation of diversity
  - Antigen presentation and Major Histoincompatibility (MHC) antigens
  - Thymus and T cell selection
  - Autoimmunity
  - Cytotoxic T cells and NK cells
  - Th1 and Th2 cells, regulatory T cells
  - Allergies
  - Hypersensitivities
  - Vaccines, immune-therapeutic interventions

Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"
Nutrition and Performance

For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a “Sessionsprüfung”. All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Domain A - Subject-specific Competencies

Concepts and Theories
Assessed

Techniques and Technologies
Assessed

Domain B - Method-specific Competencies

Analytical Competencies
Not assessed

Decision-making
Assessed

Media and Digital Technologies
Not assessed

Problem-solving
Assessed

Domain C - Social Competencies

Communication
Not assessed

Cooperation and Teamwork
Not assessed

Customer Orientation
Not assessed

Leadership and Responsibility
Not assessed

Self-presentation and Social Influence
Not assessed

Sensitivity to Diversity
Assessed

Negotiation
Not assessed

Domain D - Personal Competencies

Adaptability and Flexibility
Not assessed

Creative Thinking
Not assessed

Critical Thinking
Assessed

Integrity and Work Ethics
Not assessed

Self-awareness and Self-reflection
Assessed

Self-direction and Self-management
Assessed

Cellular Biochemistry (Part I)

551-0319-00L

W
3 credits
2V

U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Prerequisites / notice
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Molecular Biology of Foodborne Pathogens

752-4009-00L

W
3 credits
2V

M. Loessner, M. Schmelcher, M. Schuppler, E. Wetter Slack

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human host. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Literature
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

Nutrition and Performance

752-6403-00L

W
2 credits
2V

S. Mettler, M. B. Zimmermann

Abstract
The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective
To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during and after exercise.

Content
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is the goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Literature
Lecture slides and required handouts will be available on the ETH website (moodle).

Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.
Prerequisites / notice

General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on basic nutrition and biochemistry knowledge to address exercise and performance related aspects of nutrition.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

► Practical Training

Practical Training (former name: Practical Training and Semester project) only for majors mentioned below:
- Human Movement Science and Sport
- Medical Technology
- Molecular Health Sciences
- Neurosciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-2110-00L</td>
<td>Practical Training 12 Weeks (Job or Research Oriented)</td>
<td>W</td>
<td>15 credits</td>
<td></td>
<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
<td>Practical Training Internships are either research-oriented for exercising scientific (laboratory) methods or job-related for giving insight into the future world of work (industry, services, school).</td>
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<tr>
<td>Objective</td>
<td>Students should exercise scientific working and/or get realistic insights into future jobs.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This version of internships lasts for at least 12 weeks full time equivalent.</td>
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<tr>
<td>376-2111-00L</td>
<td>Practical Training 8 Weeks (Job or Research Oriented)</td>
<td>W</td>
<td>10 credits</td>
<td></td>
<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
<td>Practical Training Internships are either research-oriented for exercising scientific (laboratory) methods or job-related for giving insight into the future world of work (industry, services, school).</td>
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<td>Prerequisites / notice</td>
<td>This version of internships lasts for at least 8 weeks full time equivalent.</td>
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<tr>
<td>376-2112-00L</td>
<td>Practical Training 4 Weeks (Job or Research Oriented)</td>
<td>W</td>
<td>5 credits</td>
<td></td>
<td>Supervisors</td>
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<tr>
<td>Abstract</td>
<td>Practical Training Internships are either research-oriented for exercising scientific (laboratory) methods or job-related for giving insight into the future world of work (industry, services, school).</td>
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<tr>
<td>Objective</td>
<td>Students should exercise scientific working and/or get realistic insights into future jobs.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This version of internships lasts for at least 4 weeks full time equivalent.</td>
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</table>

► GESS Science in Perspective

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-HEST.

► Research Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-2100-00L</td>
<td>Research Internship</td>
<td>O</td>
<td>15 credits</td>
<td></td>
<td>Supervisors</td>
</tr>
<tr>
<td>Abstract</td>
<td>12-week internship intended for exercising (independent) scientific working.</td>
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<tr>
<td>Objective</td>
<td>Students shall exercise scientific working as preparation for their master thesis.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The Research Internship lasts for at least 12 weeks full time equivalent. It can be combined with the Master Thesis.</td>
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</tbody>
</table>

► Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-2000-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>71D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>
| Abstract        | Only students fulfilling the following criteria can start with their master thesis:
a. successful completion of the bachelor programme; b. fulfillment of any additional requirements necessary to gain admission to the master programme. |
| Objective       | The students shall demonstrate their ability to carry out a structured, scientific piece of work independently. |
| Prerequisites / notice | The Master Thesis can only be started after the Bachelor Degree was obtained and/or master admission requirements have been fulfilled. |

► Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0253-AAL</td>
<td>Mathematics I &amp; II Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td>E-</td>
<td>13 credits</td>
<td>28R</td>
<td>L. Halbeisen</td>
</tr>
<tr>
<td>Abstract</td>
<td>Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
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<tr>
<td></td>
<td>Mathematics I covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.</td>
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<tr>
<td></td>
<td>Main focus of Mathematics II: multivariable calculus and partial differential equations.</td>
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</tbody>
</table>
Introduction to the scientific methodology. The student should develop his/her capability to turn physical observations into mathematical models, and to solve the latter. The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.

**Objective**

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

**Content**

1. Linear Algebra and Complex Numbers:
   - systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.
   - review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

2. Single-Variable Calculus:
   - separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

3. Ordinary Differential Equations:
   - functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.

4. Multivariable Integral Calculus:
   - multiple integrals, line and surface integrals, work and flow, Green, Gauss and Stokes theorems, applications.

5. Partial Differential Equations:
   - separation of variables, Fourier series, heat equation, wave equation, Laplace equation, Fourier transform.

6. Ordinary Differential Equations:

**Prerequisites / notice**

- Prerequisites: familiarity with the basic notions from Calculus, in particular those of function and derivative.
- Assistance: Tuesdays and Wednesdays 17-19h, in Room HG E 41.

**Literature**

- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).
- Thomas, G. B.: Thomas’ Calculus, Parts 2 (Pearson Addison-Wesley).

**Enrolment**

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

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

**Abstract**

Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**

“Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.”

**Content**

Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

**Objective**

Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

**Content**

**Abstract**

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

**Objective**

The student should acquire an overview over the basic concepts in mechanics.

**Literature**

- Chapters: 1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5)

**Enrolment**

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

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

**Abstract**

Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**

“Students are able to describe the human body as a mechanical system. They analyse and describe human movement according to the laws of mechanics.”

**Content**

Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

**Objective**

Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

**Content**

**Abstract**

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

**Objective**

The student should acquire an overview over the basic concepts in mechanics.

**Literature**

- Chapters: 1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5)

**Enrolment**

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

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

**Abstract**

Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

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**Objective**

Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

**Content**

**Abstract**

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

**Objective**

The student should acquire an overview over the basic concepts in mechanics.

**Literature**

- Chapters: 1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5)

**Enrolment**

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

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

The course covers the following topics:

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content

Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes

Handouts are deposited online (moodle).

Literature


(available online via ETH library)

Handouts and references therin.

Health Sciences and Technology Master - Key for Type

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

Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
High-Energy Physics (Joint Master with IP Paris)

► Core Subjects

►► Core Courses in Theoretical Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>G. M. Graf</td>
</tr>
</tbody>
</table>

Special Students UZH must book the module PHY551 directly at UZH.

Abstract
This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity.

Topics include:
- Relativistic quantum mechanics
- Quantisation of bosonic and fermionic fields
- Interactions in perturbation theory
- Scattering processes and decays
- Elementary processes in QED
- Radiative corrections

Objective
The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.

Lecture notes
Will be provided as the course progresses.

Taught competencies

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

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

- Domain C - Social Competencies
  - Communication

- Domain D - Personal Competencies
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking

- Integrity and Work Ethics

- Self-awareness and Self-reflection

- Self-direction and Self-management

►► Core Courses in Experimental Physics

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0891-00L</td>
<td>Phenomenology of Particle Physics I</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>P. Crivelli, A. de Cosa</td>
</tr>
</tbody>
</table>

Abstract
Topics to be covered in Phenomenology of Particle Physics I:
- Relativistic kinematics
- Decay rates and cross sections
- The Dirac equation
- From the S-matrix to the Feynman rules of QED
- Scattering processes in QED
- Experimental tests of QED
- Hadron spectroscopy
- Unitary symmetries and QCD
- QCD and alpha_s running
- QCD in e^+e^- annihilation
- Experimental tests of QCD in e^+e^- annihilation

Objective
Introduction to modern particle physics

Content
Topics to be covered in Phenomenology of Particle Physics I:
- Relativistic kinematics
- Decay rates and cross sections
- The Dirac equation
- From the S-matrix to the Feynman rules of QED
- Scattering processes in QED
- Experimental tests of QED
- Hadron spectroscopy
- Unitary symmetries and QCD
- QCD and alpha_s running
- QCD in e^+e^- annihilation
- Experimental tests of QCD in e^+e^- annihilation

Literature
As described in the entity: Lernmaterialien

► Electives

►► Optional Subjects in Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0715-00L</td>
<td>Low Energy Particle Physics</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>A. Soter, P. A. Schmidt-Wellenburg</td>
</tr>
</tbody>
</table>
Low energy particle physics provides complementary information to high energy physics with colliders. In this lecture, we will concentrate on flagship experiments which have significantly improved our understanding of particle physics today, concentrating mainly on precision experiments with neutrons, muons and exotic atoms.

You will be able to present and discuss:
- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics

Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrons and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:
- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
- various techniques: detectors, cryogenics, particle beams, laser cooling....

Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
Rauch & Werner: "Neutron Interferometry"
Carlile & Willis: "Experimental Neutron Scattering"
Byrne: "Neutrons, Nuclei and Matter"
Klapdor-Kleingrothaus: "Non Accelerator Particle Physics"

Prerequisites / notice
Einführung in die Kern- und Teilchenphysik / Introduction to Nuclear- and Particle-Physics

402-0725-00L Experimental Methods and Instruments of Particle Physics
W 6 credits 3V+1U U. Langenegger, T. Schietinger, University lecturers

Abstract
Physics and design of particle accelerators.
Basics and concepts of particle detectors.
Track- and vertex-detectors, calorimetry, particle identification.
Simulation methods, readout electronics, trigger and data acquisition.
Examples of key experiments.

Objective
Acquire an in-depth understanding and overview of the essential elements of experimental methods in particle physics, including accelerators and experiments.

Content
1. Examples of modern experiments
2. Basics: Bethe-Bloch, radiation length, nucl. interaction length, fixed-target vs. collider, principles of measurements: energy- and momentum-conservation, etc.
3. Physics and layout of accelerators
4. Charged particle tracking and vertexing
5. Calorimetry
6. Particle identification
7. Analysis methods: invariant and missing mass, jet algorithms, b-tagging
8. Special detectors: extended airshower detectors and cryogenic detectors
9. MC simulations (GEANT), trigger, readout, electronics

402-0713-00L Astro-Particle Physics I
W 6 credits 2V+1U A. Biland

Abstract
This lecture gives an overview of the present research in the field of Astro-Particle Physics, including the different experimental techniques. In the first semester, main topics are the charged cosmic rays including the antimatter problem. The second semester focuses on the neutral components of the cosmic rays as well as on some aspects of Dark Matter.

Objective
Successful students know:
- experimental methods to measure cosmic ray particles over full energy range
- current knowledge about the composition of cosmic ray
- possible cosmic acceleration mechanisms
- correlation between astronomical object classes and cosmic accelerators
- information about our galaxy and cosmology gained from observations of cosmic ray

Content
First semester (Astro-Particle Physics I):
- definition of 'Astro-Particle Physics'
- important historical experiments
- chemical composition of the cosmic rays
- direct observations of cosmic rays
- indirect observations of cosmic rays
- 'extended air showers' and 'cosmic muons'
- 'knee' and 'ankle' in the energy spectrum
- the 'anti-matter problem' and the Big Bang
- 'cosmic accelerators'

Lecture notes
See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/
An introduction to the theoretical aspects and experimental tests of QCD, with emphasis on perturbative QCD and related experiments at lepton and hadron colliders.

**Prerequisites / notice**
Prerequisites: Quantum Field Theory 1 or Quantum Field Theory 2
Recommended: Quantum Field Theory 2, Advanced Field Theory, General Relativity

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### Neutrino Physics

**Abstract**
The theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, interactions with leptons and quarks).

**Objective**
Introduction to the physics of neutrinos with special consideration of phenomena connected with neutrino masses.

**Lecture notes**
Script

**Literature**

---

### General Relativity

**Abstract**
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.

**Objective**
Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

**Content**
Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

**Literature**
Suggested textbooks:
- C. Misner, K, Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- R. Wald - General Relativity
- S. Weinberg - Gravitation and Cosmology

---

### Particle Accelerator Physics and Modeling I

**Abstract**
This is the first of two courses, introducing particle accelerators from a theoretical point of view and covers state-of-the-art modelling techniques.

**Objective**
You understand the building blocks of particle accelerators. Modern analysis tools allows you to model state-of-the-art particle accelerators. In some of the exercises you will be confronted with next generation machines. We will develop a Python (or Julia) simulation tool (pyAccelLEGOrator or jAcceLEGOrator) that reflects the theory from the lecture.

**Content**
Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

---

### QCD: Theory and Experiment

**Abstract**
An introduction to the theoretical aspects and experimental tests of QCD, with emphasis on perturbative QCD and related experiments at colliders.

**Objective**
Knowledge acquired on basics of perturbative QCD, both of theoretical and experimental nature. Ability to perform simple calculations of perturbative QCD, as well as to understand modern publications on theoretical and experimental aspects of perturbative QCD.

**Content**
QCD Lagrangian and Feynman Rules
QCD running coupling
Parton model
DGLAP
Basic processes
Experimental tests at lepton and hadron colliders
Measurements of the strong coupling constant

**Literature**
2) R. K. Ellis, W. J. Stirling, B. R. Webber : "QCD and Collider Physics" (Cambridge Monographs on Particle Physics, Nuclear Physics & Cosmology)

**Prerequisites / notice**
Will be given as block course, language: English.
For students of both ETH and University of Zurich.
## Objective

Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

## Content

- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
  - D-branes, T-duality
- supergravity as a low-energy effective theory, strings on curved backgrounds
- two-dimensional field theories (classical/quantum, conformal/non-conformal)

## Literature


## Prerequisites / notice

Recommended: Quantum Field Theory I (in parallel)

### 402-0845-80L Scattering Amplitudes in Quantum Field Theories

**W** 6 credits  2V+1U  University lecturers

**Abstract**

This course provides a pedagogical introduction to an advanced topic in Quantum Field Theories, which has undergone a tremendous progress in the new millennium: scattering amplitudes and on-shell methods.

**Objective**

Students that complete the course will be able to understand the basics of the modern methods to compute scattering amplitudes, to perform simple calculations and to read modern publications on this research field.

**Content**

This course covers the basic concepts of:

- spinor helicity formalism
- colour decompositions
- BCFW on-shell recursion relations
- BCJ colour-kinematics duality
- Feynman integrals: IBPs and differential equations
- analytic and algebraic structure of loop-level amplitudes:
  - Hopf algebras, symbols and coproducts
  - multiple polylogarithms (a.k.a. as iterated integrals on the Riemann sphere)
  - Steinmann relations
  - coaction principle
  - elliptic and modular-form integrals (a.k.a. as iterated integrals on the torus)

**Lecture notes**

Will be provided at the Moodle site for the course.

**Literature**

Will be provided at the Moodle site for the course.

**Prerequisites / notice**

A basic knowledge of Feynman rules in scalar field theories and in Yang-Mills theory is assumed.

QFT-I and Introduction to Quantum Chromodynamics are highly recommended.

### 402-0886-00L Quantum Chromodynamics

**W** 6 credits  2V+1U  T. K. Gehmann

**Abstract**

The course presents the quantum field theory of the strong interaction (quantum chromodynamics, QCD) and discusses its applications to particle physics observables.

**Objective**

The course aims to familiarize its students with the concepts and applications of QCD and to introduce them to modern techniques for computations in QCD.

**Content**

Contents:

- Review of non-Abelian gauge theories and their quantization
- Spinor-helicity formalism
- Renormalization of QCD and running coupling constant
- Basic strong interaction processes
- Perturbation theory techniques: loops and phase space
- QCD perturbation theory and applications
- Proton structure in QCD
- Resummation of large logarithmic corrections
- Effective field theories
- Non-perturbative methods

**Prerequisites / notice**

The course assumes prior knowledge of the content of the quantum field theory 1+2 lectures.

### 402-0845-61L Effective Field Theories for Particle Physics

**W** 6 credits  2V+1U  P. Stoffer

**Abstract**

The focus of the course is on Effective Field Theories (EFTs) and their interplay with dispersion theory. These topics will be discussed both in general terms and with specific phenomenological applications in the context of physics beyond the Standard Model, effective description of the weak interaction, as well as the description of non-perturbative strong interaction at low energies.

**Objective**

This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model.

In the next part of the course, we will discuss Chiral Perturbation Theory (ChPT), the low-energy effective theory of Quantum Chromodynamics (QCD). We will briefly discuss the application of this concept to describe a class of theories beyond the SM in which the SM Higgs arises as a composite state of a new confining sector.

The second focus of the course is on dispersion theory and its interplay with EFTs. We will discuss how to make use of the constraints from unitarity of the S-matrix and analyticity of scattering amplitudes, in order to extend the range of validity of the theoretical description compared to pure EFT methods. We will also discuss how to obtain constraints on EFT parameters from unitarity and analyticity. We will discuss the application of these methods both in the context of low-energy strong interaction and physics beyond the Standard Model.
# Optional Subjects in Mathematics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3531-00L</td>
<td>Differential Geometry I</td>
<td>W</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>J. Serra</td>
</tr>
<tr>
<td>401-3461-00L</td>
<td>Functional Analysis I</td>
<td>W</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>J. Teichmann</td>
</tr>
</tbody>
</table>

## Abstract


## Objective

Provide insightful knowledge about the classical theory of curves and surfaces (which is the precursor of modern differential geometry). Invite students to use and sharpen their geometric intuition.

## Lecture notes

Partial lecture notes are available from Prof. Lang’s website [https://people.math.ethz.ch/~lang/](https://people.math.ethz.ch/~lang/)

## Literature

- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- John M. Lee: Introduction to Smooth Manifolds
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie, Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds

---

## Proseminars and Semester Papers

To organise a semester project take contact with one of the instructors.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0717-MSL</td>
<td>Particle Physics at CERN</td>
<td>W</td>
<td>8 credits</td>
<td>15P</td>
<td>W. Lustermann</td>
</tr>
</tbody>
</table>

## Abstract

During the semester break participating students stay for 4 weeks at CERN and perform experimental work relevant to our particle physics projects. Dates to be agreed upon.

## Objective

Students learn, by doing, the needed skills to perform a small particle physics experiment: setup, problem solving, data taking, analysis, interpretation and presentation in a written report of publication quality.

## Content

Detailed information in: [https://ethteilchenpraktikum.web.cern.ch/](https://ethteilchenpraktikum.web.cern.ch/)
The course will not follow the historical trajectory of experimental particle physics. It will instead try to give a modern view of the results of some lectures, but the focus lies on the practical aspects of experimenting.

Students learn all the different steps it takes to perform a complete particle physics experiment in a small team. They acquire skills to do this themselves in the team, including design, construction, data taking and data analysis.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Language of instruction: English or German</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0719-MSL</td>
<td></td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>During semester breaks 6-12 students stay for 3 weeks at PSI and participate in a hands-on course on experimental particle physics. A small real experiment is performed in common, including apparatus design, construction, running and data analysis. The course includes some lectures, but the focus lies on the practical aspects of experimenting.</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Students learn all the different steps it takes to perform a complete particle physics experiment in a small team. They acquire skills to do this themselves in the team, including design, construction, data taking and data analysis.</td>
</tr>
<tr>
<td>402-0210-MSL</td>
<td>Proseminar Theoretical Physics ■</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>A guided self-study of original papers and of advanced textbooks in theoretical physics. Within the general topic, determined each semester, participants give a presentation on a particular subject and deliver a written report.</td>
</tr>
<tr>
<td>402-0217-MSL</td>
<td>Semester Project in Theoretical Physics ■</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course unit is an alternative if no suitable &quot;Proseminar Theoretical Physics&quot; is available of if the proseminar is already overbooked. Die Leistungskontrolle erfolgt aufgrund eines oder mehrerer schriftlicher Berichte bzw. einer schriftlichen Arbeit. Vorträge können ein zusätzlicher Bestandteil der Leistungskontrolle sein.</td>
</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
</tr>
<tr>
<td>402-0740-00L</td>
<td>Experimental Foundations of Particle Physics ■</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The Standard Model of particle physics is a monumental achievement of human ingenuity. While typically approached from the theoretical side, in this proseminar we will collect the experimental evidence upon which the Standard Model has been built.</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>The course will not follow the historical trajectory of experimental particle physics. It will instead try to give a modern view of the results of the experiments and show where they fit in the theoretical construction. The students will read the original papers collected in the seminal text by Cahn and Goldhaber. The theory will be distilled to the very basics using the textbook by Bettini.</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Cahn, Goldhaber &quot;Experimental Foundations of Particle Physics&quot; (2nd edition), Cambridge University Press, Bettini, &quot;Introduction to Elementary Particle Physics&quot; Cambridge University Press</td>
</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Recommended: Phenomenology of Particle Physics I (or II) (in parallel)</td>
</tr>
<tr>
<td><strong>Taught competencies</strong></td>
<td>Domain A - Subject-specific Competencies Concepts and Theories assessed</td>
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<td>Domain B - Method-specific Competencies Analytical Competencies assessed</td>
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<td></td>
<td>Domain C - Social Competencies Communication assessed</td>
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<td></td>
<td>Domain D - Personal Competencies Critical Thinking assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management assessed</td>
</tr>
<tr>
<td>402-0215-MSL</td>
<td>Experimental Semester Project in Physics ■</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The aim of the project is to give the student experience in working in a research environment, carrying out physics experiments, analysing and interpreting the resulting data. Die Leistungskontrolle erfolgt aufgrund eines oder mehrerer schriftlicher Berichte bzw. einer schriftlichen Arbeit. Ein Vortrag über die gewonnenen Ergebnisse ist ein obligatorischer Bestandteil der Leistungskontrolle.</td>
</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
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</tr>
<tr>
<td>402-2000-00L</td>
<td>Scientific Works in Physics</td>
</tr>
<tr>
<td><strong>Number</strong></td>
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<tr>
<td><strong>Title</strong></td>
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<td><strong>Hours</strong></td>
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<tr>
<td><strong>Lecturers</strong></td>
<td>C. Eichler</td>
</tr>
</tbody>
</table>

**GESS Science in Perspective**

- see GESS Science in Perspective: Language Courses ETH UZH
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

**Recommended GESS Science in Perspective (Type B) for D-PHYS:**

**Master's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>402-2000-00L</td>
<td>Scientific Works in Physics</td>
<td>O</td>
<td>0</td>
<td></td>
<td>C. Eichler</td>
</tr>
</tbody>
</table>
Target audience:
Master students who cannot document to have received an adequate training in working scientifically.

Directive

Abstract
Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective
Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

462-0900-00L Master's Thesis
Further information: www.phys.ethz.ch/phys/education/master/msc-theses

Abstract
The Master's thesis is normally conducted in the fourth semester and concludes the degree programme. With the Master's thesis students verify their ability to undertake independent and scientifically structured work in the area of high energy physics.

Prerequisites / notice
The time limit for completing the Master's thesis is six months.

High-Energy Physics (Joint Master with IP Paris) - Key for Type

<table>
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<tr>
<th>Key for Type</th>
<th>O</th>
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Key for Hours

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<tbody>
<tr>
<td></td>
<td>lecture</td>
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<td>seminar</td>
<td>colloquium</td>
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<td>practical/laboratory course</td>
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<td>independent project</td>
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<td>diploma thesis</td>
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<td>revision course / private study</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Human Medicine Bachelor

First Year Examinations

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>377-0105-00L</td>
<td>Musculoskeletal System</td>
<td>O</td>
<td>5</td>
<td>5V</td>
<td>J. Goldhahn, O. Distler, C. Maake, M. Steinwachs, R. Stocker</td>
</tr>
<tr>
<td>377-0107-00L</td>
<td>Nervous System</td>
<td>O</td>
<td>5</td>
<td>5V</td>
<td>D. P. Wolfer, I. Amrein, J. Bohacek, D. Burdakov, G. Schratt, L. Slomianka, O. Ullrich, N. Wenderoth, further lecturers</td>
</tr>
<tr>
<td>551-0033-00L</td>
<td>Molecular Genetics and Cell Biology</td>
<td>O</td>
<td>5</td>
<td>5G</td>
<td>J. Corn, F. Allain, K. Köhler</td>
</tr>
<tr>
<td>529-5000-00L</td>
<td>Chemistry (for Medical Students)</td>
<td>O</td>
<td>4</td>
<td>3+1U</td>
<td>S. Wolfrum</td>
</tr>
</tbody>
</table>

Abstract
Structure and function of the human musculoskeletal system including its major disorders (acute and chronic).

Objective
- The students are able to participate in team discussions with correct technical language in the clinical daily routine.
- The students are able to describe the function of the musculoskeletal system of healthy people in a physiologically correct way.
- The students are able to contribute to a therapy plan based on their knowledge of the regenerative capacity of the different tissues in the musculoskeletal system.
- The students recognize pain as a leading symptom in diagnostics and successful therapy.
- The students can assign and compare treatment methods for the most common acute and chronic clinical pictures.

Content
The students learn about the structure and function of the musculoskeletal system and major disorders on the basis of exemplary clinical pictures. They also learn:
- About its tissue types as well as its function and regeneration.
- Important acute and chronic clinical pictures and their therapeutic principles.

In addition, further clinical pictures are presented in the form of seminars.

Abstract
Structure and function of the central and peripheral nervous system including its major disorders.

Objective
Upon successful completion of this module, students should be able to:
1. distinguish important cell types of the nervous system (neurons, glial cells) on the basis of their structure and function;
2. correctly describe the neurophysiological basics of stimulus conduction and processing in the peripheral and central nervous system;
3. correctly name the organ structures and circuits involved in the development of the peripheral and central nervous system;
4. associate the different brain areas with corresponding functions in homeostasis, sensory, motor and cognitive functions;
5. identify clinical pictures associated with the loss of function of certain structures of the central and peripheral nervous system and to understand the mode of action of current therapeutic approaches.

Content
In this module, students get an overview of the structure (anatomy) and function (physiology) of the peripheral and central nervous system as well as selected neurological diseases (pathophysiology).

The module is subdivided into a total of six subject areas: 1. basics of neurophysiology, stimulus conduction and processing using the example of the motor end plate, peripheral nervous system, associated clinical pictures (myasthenia gravis) 2. structure, circuits and pathways in the spinal cord, spinal nerves, motor stimulus conduction in the spinal cord, spinal cord lesions and pain 3. anatomy and function of the brain stem and cranial nerves and their significance for motor and sensory functions, lesions (brain stem syndromes) 4. anatomy and function of basal ganglia, thalamus and hypothalamus, control of the autonomic nervous system (homeostasis, food and water intake), basal ganglia defects using Parkinson's disease as an example 5. anatomy and function of the cerebellum and vestibular system, fine control of motor functions, associative learning, cerebellar symptoms (ataxias), organ of equilibrium 6. anatomy and function of the cerebrum, sensory and motor processing, cognition, learning and memory, neurodegenerative (Alzheimer) and neuropsychiatric (schizophrenia) disorders

Abstract
This course teaches the basic principles of evolution, cell biology, molecular biology, genetics and developmental biology using the example of humans.

Objective
1) Students can explain the importance of evolution for the development of humans and diseases.
2) The students know the cell as the smallest unit of the body. They can explain how the functions of the cell are disturbed in certain diseases and where therapies intervene. They can describe the multiplication of cells in the body and show how errors in this multiplication can lead to diseases.
3) The students know DNA as the basis of life. They can explain how the DNA information is stored and how this information can be reproduced and protected from damage. They can describe how the information is read and translated into proteins. They can explain which mechanisms at the level of DNA, RNA and proteins can cause diseases.
4) Students can explain which technologies can be used to diagnose and treat diseases.
5) Students can explain how people differ genetically and know the molecular basis of these differences. They can explain how these differences can lead to diseases and why some of these differences do not affect diseases.
6) The students know the molecular causes of the most common hereditary diseases and can determine the probability of occurrence and transmission to offspring.
7) Students can explain the biochemical and molecular basis of human reproduction and know the basic principles of human embryonic development. The students can explain which mechanisms can be disturbed by a faulty development.

Abstract
The lecture teaches the most important fundamental concepts in chemistry (atomic structure, chemical bonds, thermodynamics and kinetics of chemical reactions, acid-base equilibria, types and reactivity of organic compounds, stereochemistry, biomolecules).

Objective
Understanding of the basic concepts of chemistry. Understanding the importance of chemical processes in human physiology and in the diagnosis and treatment of human diseases.

Content
The lecture covers the fundamental concepts of chemistry. The organization of the lecture is guided by the two textbooks "Chemie für Mediziner" by Zeeck et al. and Schmuck et al., respectively, referred to below. Accordingly, the following major subject areas will be covered: Atomic structure, periodic table of the elements, types of chemical bonds, states of matter, heterogeneous equilibria, thermodynamics and kinetics of chemical reactions, salt solutions, acids and bases, oxidation and reduction, metal complexes, fundamentals of organic chemistry, important classes of organic compounds and their reactivities, stereochemistry, amino acids and peptides, carbohydrates, lipids, heterocycles, spectroscopy in chemistry and medicine.

Lecture notes
Scripts for individual subject areas will be provided electronically prior to the corresponding lectures.

Literature
There are no English translations of these textbooks.
Prerequisites / notice
There are no specific requirements.

★ ★ First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-0281-00L</td>
<td>Mathematics I</td>
<td>O</td>
<td>4 credits</td>
<td>3V+1U</td>
<td>L. Keller</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction of mathematics as the universal language for scientific facts: The lecture aims on one hand at learning and exercising the mathematical trade and in the other hand at applying the learnt concept to medical, biological, chemical and mechanical problems.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Simple and complex facts can be described and analysed using mathematical tools. Introduction to calculus in one dimension. Used concepts: the notion of a function, of the derivative and the integral, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. Applications e.g. to prognoses, modeling action and dosage of drugs or tumor growth.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Functions of one variable: the notion of a function, of the derivative, the idea of a differential equation, complex numbers, Taylor polynomials and Taylor series. The integral of a function of one variable.</td>
<td></td>
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<tr>
<td><strong>Literature</strong></td>
<td>G. B. Thomas, M. D. Weir, J. Hass: Analysis 1, Lehr- und Übungsbuch, Pearson-Verlag further reading suggestions will be indicated during the lecture</td>
<td></td>
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</tbody>
</table>

**Taught competencies**

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

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

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

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

★ Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Fundamental principles of human medicine, Basic Life Support (BLS) and introduction to histology and microscopy.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After completion of the course, the students:</td>
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<tr>
<td>- have a basic understanding of elementary building blocks and processes as a basis for human medicine, e.g. cell structure and cycle.</td>
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<td>- know basic terminology of anatomy.</td>
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<td>- understand the process of medical care from first aid to rehabilitation.</td>
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<td>- understand the advantages and disadvantages of emergency diagnostics, especially ultrasound.</td>
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<td>- know the basics of microscopy and histology.</td>
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<td>- have learned the basics of Basic Life Support:</td>
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<td>- recognize the symptoms of cardiovascular arrest.</td>
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<td>- alarm in an emergency according to the situation.</td>
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<td>- If available, they organize an AED and use it correctly and as quickly as possible.</td>
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<td>- perform sufficient chest compressions on the phantom.</td>
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<td>- perform effective ventilation on the phantom using a pocket mask.</td>
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<td>- will identify possible ventilation complications. Under certain circumstances, they will not attempt further ventilation.</td>
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<td>- will identify the limits of cardiopulmonary resuscitation.</td>
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<td>- under stress, they do not risk their own or other “helpers” lives.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Based on a complex clinical case, students are familiarized with the course of medical care from initial treatment to rehabilitation. Basic terms, modules and processes are introduced. In addition, the students experience the basics of imaging techniques, especially ultrasound. The students complete the Basic Life Support course. After this training sequence, all participants should be able to initiate resuscitation measures in private and in-hospital settings. The students experience learning, teaching and working in the hospital sector as a social process and teamwork in which all senses and a wide range of skills are needed. In addition, the students experience in three workshops the basic process of a physiotherapeutic intervention with the concepts of clinical reasoning, therapeutic aspects and therapy progression. An intensive course in microscopy/histology enables students to perform microscopy independently and to understand histological sections of a histological sample, but also online.</td>
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</table>

| 377-0111-00L | Medical Anamnesis Technique                                   | O    | 2 credits | 2G | S. Markun, S. Neuner-Jehle, N. Scherz |
| **Abstract** | Interviewing techniques to acquire medically relevant information and building an adequate physician-patient relationship. |
The course will focus on the components and functions of the hematopoietic and the immune systems and on diseases affecting or caused by these systems.

**Content**

1. Introduction to hematopoiesis, hematopoietic growth factors, hematopoietic transcription factors, erythrocyte physiology and iron metabolism; the principles of blood groups and blood transfusions; the principles of coagulation and the pharmacology of coagulation; the role of platelets and pharmacological platelet inhibition; to define thrombophilia and to understand thrombotic events; the role of leukocytes in health and disease; the analysis of blood samples; the principles of hematopoietic stem cell transplantation.

2. The development of the immune system; the structure and function of primary and secondary lymphoid organs; the cellular and molecular mechanisms of the innate and adaptive immune systems; the effector mechanisms of immune responses against pathogens; basic concepts of immune-mediated diseases (allergy and autoimmunity), tumor immunology, immunodeficiency, organ transplantation; basic knowledge of therapies.

**Abstract**

Mixed teaching methods, each with a theoretical part followed by practice in small groups and application to real patients. The most central components of communication and anamnesis techniques are reduced to their smallest components and each student performs each component at least once. At the end of the module, the components are practiced in an integrated manner to form a complete anamnesis.

### Courses in Organ Systems and Clinical Practice

#### Examination Block A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

**Objective**

The students can build a relationship with the patient and, based on this, collect the essential concerns and information from the patient in a structured way.

The students know:
- the theoretical basics of communication;
- the structural components of the anamnesis;
- certain communication techniques.

The students can:
- pre-structure an anamnesis (structural components by heart);
- take a simple (but complete) anamnesis.

### Content

**Abstract**

This course will focus on the components and functions of the hematopoietic and the immune systems and on diseases affecting or caused by these systems.

**Objective**

1. The organization and development of hematopoiesis including hematopoietic stem cell development; the role of hematopoietic growth factors and transcription factors in hematopoiesis; the role of hemoglobin in health and disease; erythrocyte physiology and iron metabolism; the principles of blood groups and blood transfusions; the principles of coagulation and the pharmacology of coagulation; the role of platelets and pharmacological platelet inhibition; to define thrombophilia and to understand thrombotic events; the role of leukocytes in health and disease; the analysis of blood samples; the principles of hematopoietic stem cell transplantation.

2. The development of the immune system; the structure and function of primary and secondary lymphoid organs; the cellular and molecular mechanisms of the innate and adaptive immune systems; the effector mechanisms of immune responses against pathogens; basic concepts of immune-mediated diseases (allergy and autoimmunity), tumor immunology, immunodeficiency, organ transplantation; basic knowledge of therapies.

**Content**

1. Introduction to hematopoiesis, hematopoietic growth factors, hematopoietic transcription factors, erythrocyte physiology, blood groups, blood transfusion, iron metabolism, platelets, coagulation cascade, fibrinolysis, hemoglobin, hemoglobinopathies, leukocytes (granulocytes, monocytes), clinical presentation of neutropenia, pharmacology of hemostasis, clinical presentation of thrombophilia, basics of hematopoietic stem cell transplantation, some aspects of laboratory medicine in hematopathology, virtual microscopy of blood and bone marrow smears.

2. Structure and anatomical position of primary and secondary lymphoid organs, cells and molecules of the immune system, T and B cell development and receptor diversity, major histocompatibility complex (MHC) and antigen presentation, effector B cells and antibodies, effector T cells, regulatory T cells and cytokines, allergy and hypersensitivities, autoimmunity and anti-inflammatory drugs, transplantation and immunosuppressive drugs, immunodeficiency, immune response in cancer and immunotherapies.

**Prerequisites / notice**

The Immune system part of this course builds on the content of the "Infection and Immunology" course.

**Number**

377-0301-03L

**Title**

Endocrinology, Metabolism<br>Only for Human Medicine BSc

**Abstract**

Discussion of normal structure and function of the endocrine systems, their interaction with the autonomic nervous system and their role in metabolism. In addition, pathophysiological and clinical aspects, diagnostics and therapeutic concepts of the most important endocrine diseases and related metabolic disorders as well as respective preventive measures are addressed.

**Prerequisites / notice**

Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0200-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hombostase

**Number**

377-0301-11L

**Title**

Blood, Immune System<br>Only for Human Medicine BSc

**Abstract**

The course is supported by a Moodle page through which students have access to all necessary documentation.

**Prerequisites / notice**

The course is supported by a Moodle page through which students have access to all necessary documentation.

**Suggested reference books include:**

- Blood: Hoffbrand's Essential Haematology
- Immune system: Herbert Hof, Rüdiger Dörries; unter Mitarbeit von: Gernot Geginat, Dirk Schlüter and Constanze Wendt Medizinische Mikrobiologie Thieme 2017
- http://www.library.ethz.ch/DADS/default_scope:ebi01_prod010873047
- https://institut.elsevierlibrathy.de/product/basic-immunology85281

**Number**

377-0301-02L

**Title**

Nutrition and Digestion<br>Only for Human Medicine BSc

**Abstract**

This module imparts basic knowledge about the morphology and function of the digestive system and the importance of nutrition for health. One focus is on the understanding of the relationships among food intake, digestion, nutrient absorption and metabolism including the disturbances of these processes and the related diseases.

**Objective**

The aim of this module is that the students know and understand the morphology and function of the digestive system including its associated glands as well as the importance of nutrition for health. In particular, the students shall understand the relationships between food intake and digestion as well as absorption and metabolism of particular nutrients. This knowledge shall enable the students to deduce the pathophysiology and pathology of the most important diseases of the digestive system and shall give them an idea of the pertinent diagnostics and therapy.

**Prerequisites / notice**

Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hombostase

**Number**

377-0301-05L

**Title**

Nutrition and Digestion<br>Only for Human Medicine BSc

**Abstract**

The students can build a relationship with the patient and, based on this, collect the essential concerns and information from the patient in a structured way.

The students know:
- the theoretical basics of communication;
- the structural components of the anamnesis;
- certain communication techniques.

The students can:
- pre-structure an anamnesis (structural components by heart);
- take a simple (but complete) anamnesis.

**Content**

Fundamentals of medical conversation in theory and practice

**Mixed teaching methods,** each with a theoretical part followed by practice in small groups and application to real patients. The most central components of communication and anamnesis techniques are reduced to their smallest components and each student performs each component at least once. At the end of the module, the components are practiced in an integrated manner to form a complete anamnesis.
Upon successful completion of this module, students should:

- be able to explain the systematics of the endocrine system;
- know the structure and function of the hypothalamus, pituitary gland, adrenal gland, endocrine pancreas, thyroid gland, ovaries, testes;
- know the principles and regulation of bone, calcium and phosphate metabolism, energy balance, glucose metabolism, lipid metabolism, blood pressure;
- know the hormonally regulated metabolic processes (carbohydrates, protein and fat);
- know the most important endocrine diseases and tumors, their development, clinic, diagnostics and therapy;
- know the most important measures for the prevention of metabolic diseases and the underlying mechanisms.

In this module, students learn about anatomy, physiology, and pathophysiology of the endocrine glands, as well as the clinical, diagnostic, therapeutic, and preventive aspects of the most important endocrine diseases. This includes:

- Systematics of the endocrine system: structure and anatomical location of the various endocrine glands.
- Neuronal innervation and vascular supply area of the endocrine glands.
- Hormone classes: Protein and polypeptide hormones, amino and amino acid derivatives steroid hormones, biosynthesis of protein and polypeptide hormones, biosynthesis of amino and amino acid derivatives, biosynthesis of steroid hormones, storage of hormones, secretion of hormones, transport of hormones, half-lives, degradation and excretion of hormones.
- Transmission of information by hormones: hormone action at receptors, structure and function of membrane-associated hormone receptors, structure and function of nuclear receptors, regulation of hormone secretion.
- Structure and function of the hypothalamus, structure and function of the pituitary gland.
- Structure and function of the thyroid gland, under- and over-functioning of the thyroid gland, principles of diagnostics and therapy of thyroid diseases. Symptoms, medical history and clinical examination of thyroid diseases.
- Bones, calcium and phosphate metabolism.
- Regulation of glucose, lipid and protein metabolism, eating disorders, etiology, diagnostics, therapy and prevention of adipositas.
- Structure and function of the adrenal gland, pathogenesis, principles of diagnostics and therapy of diseases with hyper- and hypofunction of the adrenal gland. Symptoms, anamnesis and clinical examination in case of hyper- and hypofunction of the adrenal gland.
- Structure and function of the ovaries and testis, principles of reproductive physiology.

There is no traditional script for this course. Instead the course is supported by a Moodle page through which students have access to all necessary texts, exercises, videos and activities.

The essential course material will be available on the course's Moodle Page in the form of scripts and lesson handouts. The course does not have an "official" textbook, but students may find a general reference book on the topic interesting. For this purpose the text "Endokrinologie und Stoffwechsel" von Stefan Fischli and Giatgen A. Spinas (Herausgeber), Thieme Verlag, may be helpful.

The course builds on the content of the "Chemie für Mediziner", "Biochemie", "Pathobiochemie", "Pharmakologie für Mediziner" and "Molekulare Genetik und Zellbiologie" course and "Nutrition and Digestion".

►► Examination Block B

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0083-00L</td>
<td>Physics I</td>
<td>O</td>
<td>4</td>
<td>3V+1U</td>
<td>K. S. Kirch</td>
</tr>
</tbody>
</table>

This course is an introduction to classical physics, with special focus on applications in medicine.
Obtain an understanding of basic concepts in classical physics and their application (using mathematical pre-knowledge) to the solution of simple problems, including certain applications in medicine.
Obtain an understanding of relevant quantities and of orders of magnitude.
General introduction; Positron-Emission-Tomography as appetizer, including ionising radiation; kinematics of a point mass; dynamics of a point mass (Newton's axioms and forces); physical work, power and energy; conservation of linear and angular momentum; oscillations and waves; mechanics of a rigid body; fluid mechanics; introduction to electricity.

Will be distributed at the start of the semester.

►► Additional Courses 2nd Year

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>377-0311-00L</td>
<td>Clinical Anatomy Lab</td>
<td>O</td>
<td>5</td>
<td>7P</td>
<td>J. Loffing, O. Ullrich, I. Amrein, G. Colaccio, N. Lier, further lecturers</td>
</tr>
</tbody>
</table>

Topographical Anatomy and Radioanatomy of the head, skull, central nervous system, neck and neck organs, upper and lower extremities, thoracic wall and organs, abdominal wall and organs, pelvis and pelvic organs, dorsal muscles, vessels, nerves, functions, clinical aspects. Methods: Anatomical dissection of human bodies.
Learning and understanding of the detailed composition and function of the healthy human body and ist components. Learning of selected examples of relevant radiographic anatomy and their implication in clinical medical work.

Topographic – and radiographic anatomy of selected anatomical regions. Students dissect these regions and discuss important clinical content with aid of assistants.

LE 377-0105-00L Bewegungssapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hormodase

►► Additional Courses 3rd Year

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>377-0503-01L</td>
<td>Geriatrics</td>
<td>O</td>
<td>1</td>
<td>1V</td>
<td>M. Ristow, J. Goldhahn, R. W. Kressig, M. Martin, further lecturers</td>
</tr>
</tbody>
</table>

- Fundamentals and relevance of the aging process, as well as its biochemical, physiological and evolutionary basis. Insights into its individual as well as economic impact, including interventional and pharmacological treatment options.
Upon successful completion of the module, students should be able to:
1. correctly describe the biological bases of the aging process;
2. derive physical and pharmacological choices to modulate the aging process;
3. understand the social and psychological implication of aging;
4. describe the specificities of geriatric medicine in the stationary setting;
5. identify the age-specific differences in both diagnostics and therapeutics.

**Abstract**
At the end of the module, students should be able to do the following:
- list the typical symptoms and manifestations of the disease patterns;
- list the clinical examinations of the clinical pictures and explain the findings;
- list and justify further clarifications (such as laboratory tests, imaging, etc.) of the clinical pictures;
- recognize the respective clinical pictures of this topic block based on the symptoms, clinical examinations, findings and further clarifications;
- list the possible treatment options for the disease patterns and explain the indication, prevention and risk factors;
- Early detection of clinical pictures that require rapid therapy, identification of further steps for clarification and therapy;
- describe the causes and pathophysiological basis of the disease patterns.

**Content**
Overview Rheumatology, Rheumatoid Arthritis, M. Still, Spondyloarthritis, SAPHO Syndrome, Infectious and Crystal Arthritis, Juvenile Idiopathic Arthritis, CRPS, Soft Tissue Diseases, Myopathies, Bone Diseases, Vasculitis, Collagenosis, Drug Therapy in Rheumatology, Ergonomics, Occupational Reintegration.

**Objective**
- Knowledge of the causes and pathophysiological basis of the disease patterns.
- Early detection of clinical pictures that require rapid therapy, identification of further steps for clarification and therapy;
- list the possible treatment options for the disease patterns and explain the indication, prevention and risk factors;
- recognize the respective clinical pictures of this topic block based on the symptoms, clinical examinations, findings and further clarifications;
- list the possible treatment options for the disease patterns and explain the indication, prevention and risk factors;
- list the clinical examinations of the clinical pictures and explain the findings;
- list and justify further clarifications (such as laboratory tests, imaging, etc.) of the clinical pictures;
- recognize the respective clinical pictures of this topic block based on the symptoms, clinical examinations, findings and further clarifications.

**Content**
The module Paediatrics describes the peculiarities of the paediatric anamnesis as well as selected topics of the healthy and sick child. The focus is on the newborn, development in the first years of life and adolescence. Infections, congenital heart and the most common respiratory diseases are described throughout the different age stages.

**Objective**
- Knowledge of the paediatric aspects of the medical history;
- Knowledge of the enormous variety of child development (inter- and intra-individual variability);
- Milestone concept: Assessment of the stage of development of a child in the first years of life;
- Landmark concept: first knowledge of the demilitation on normality versus disorder;
- Getting to know frequent developmental pediatric disorders;
- Getting to know and recognize respiratory diseases of the upper and lower respiratory tract.

**Content**
It describes the peculiarities of the pediatric anamnesis as well as selected topics of the healthy and sick child. The focus is on the newborn, development in the first years of life and adolescence. Infections, congenital heart, and the most common respiratory diseases are described throughout the different age stages.

**Prerequisites / notice**

**Prerequisites:**
- LE 377-0105-00L Bewegungsapparat
- LE 377-0107-00L Nervensystem
- LE 377-0201-00L Herz-Kreislauf-System
- LE 377-0203-00L Atmungs-System
- LE 377-0205-00L Nieren und Homöostase
- LE 377-0301-00L Blut, Immunsystem
- LE 377-0301-02L Ernährung und Verdauung
- LE 377-0301-03L Endokrinologie, Stoffwechsel
- LE 377-0401-00L Sinnesorgane
- LE 377-0403-00L Haut und Anhangsorgane

**Abstract**
By focusing on the 20 most frequent emergencies, the students will learn how to make quick decisions including diagnostic strategy and therapeutic measures. In practical exercises the students practice interprofessional aspects and discuss legal and ethical questions of emergency medicine.

**Content**
By focusing on the 20 most frequent emergencies, the students will learn how to make quick decisions including diagnostic strategy and therapeutic measures. In practical exercises the students practice interprofessional aspects and discuss legal and ethical questions of emergency medicine.
Objective

Perform a triage based on the assessment of the vital signs.
Collect a targeted anamnesis (max. 5-6 questions) of a patient and/or family member
Determine the status of a patient with the necessary clinical examinations.
Determine a differential diagnosis based on the targeted anamnesis and the status.
Interpret the vital signs of a patient
Interpret the results of the paraclinical examinations and confirm/reject the differential diagnosis.
Based on the differential diagnosis, determine the necessary paraclinical examinations
Determine the next steps (treatment in hospital / by family doctor / immediate measures)
Identify possible therapeutic measures

Content

Mornings – case discussions & lectures entire group:
- Hypo / Hyperglycemia
- Principles of poisoning
- Acute Dyspnoea
- Cough
- Acute Diarrhoea
- Gastrointestinal bleeding
- Acute Kidney injury
- Hypertensive Crisis
- Acute Headache
- Coma
- Chest Pain
- Syncope
- Acute Abdominal pain
- Acute blood loss
- Common Trauma
- Head Trauma
- Fever in child
- Crying child
- Seizures and convulsions
- Dyspnoea in child

Afternoon – 4 smaller groups rotating:
- Emergency room (Hospital Lugano)
- Emergency call-center / Ambulance (Croce Verde - Lugano)
- Simulation center (Lugano)
- Case discussion (Bellinzona)
- BLS Refresh

Prerequisites / notice

Voraussetzungen:
LE 377-0101-00L Grundbausteine Mensch
LE 377-0211-00L Körperliche Untersuchung
LE 377-0411-00L Internistische Untersuchung

377-0509-00L Pathology
Only for Human Medicine BSc

After successfully completing the «General Pathology» module, students should be able to
1. to describe the goals and methods of pathoanatomical diagnostics and in reference to clinical practice.
2. to name the general causes and mechanisms of disease development and the associated pathomorphological changes in cells and tissues.
3. to fundamentally link the general causes and mechanisms of disease development with the therapeutic approaches that arise from them.
4. to describe the mechanisms of general inflammation, cell damage and circulatory pathology and relate them to the pathogenesis of specific diseases.
5. to explain the basics of the classification of benign and malignant tumors.
6. to describe the value of pathoanatomical and molecular diagnostics for the predictive and prognostic stratification of patients and to fundamentally relate them to clinical therapy decisions.

After successfully completing the «Surgical Pathology» module, students should be able to
1. to name the most important organ-specific diseases of the nervous system, the endocrine system, the cardiovascular system, the respiratory system, the digestive system, the urogenital system, the musculoskeletal system and the skin and to describe their characteristic macroscopic and microscopic manifestations.
2. to relate the etiology and pathogenesis of the most important organ-specific diseases to their morphological appearance and clinical presentation.
3. to describe the etiopathogenesis of the most important organ-specific diseases and to understand the relation to the mode of action of common therapeutic approaches.
4. to describe the fundamental importance of pathology and molecular diagnostics for personalized medicine and to describe specific application examples.

Abstract

Pathology is the study of causes and effects of disease. This module pathology describes the pathogenetic processes and pathomorphological changes that occur in healthy and diseased tissues and cells of the human body. The module covers basic anatomical and surgical pathology and will cover the current and future possibilities of diagnostic practice in pathology.
After passing the module successfully, students should be able to:
1. revision and in-depth histology
2. introduction to pathology, histopathological and macroscopic tissue evaluation, postmortem diagnostics
3. introduction to causes and mechanisms of disease development
4. inflammation theory
5. cell damage and circulation pathology
6. general tumor theory
7. predictive pathology

In the module "Special Pathology" you will learn about the most important organ-specific diseases. Each half-day is built around a complex of topics related to special pathology, and is implemented using various teaching methods. The most important part is the main lecture, in which we systematically discuss the diseases of the organs and organ systems with you. Using macroscopic and microscopic slides, we will show you the relation to pathophysiology, symptomatology and medical diagnostics. We establish clinical references by broadcasting the mortality conference at the USZ. An integrated revision course and exercises based on PathoMaps offer you the opportunity to link the subject matter of the lecture with already known contents, to structure it further and to clarify open points together. A special lecture on molecular pathology, digital pathology and bioinformatics will introduce you to future technologies that are of particular importance for modern medicine.

The special pathology part covers the main topics:
1. upper and lower respiratory tract
2. lower gastrointestinal tract
3. liver, gall bladder, pancreas
4. kidney, draining urinary tract
5. male sexual organs, prostate
6. female sexual organs, mamma
7. future technologies (molecular pathology, digital pathology, bioinformatics)
8. blood and bone marrow, lymphatic system
9. endocrine organs
10. skin, bones, joints, soft tissue
11. male sexual organs, prostate
12. nephropathy

Prerequisites / notice
Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauß-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Hohmöstase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

777-0513-00L Ethics and Legal Aspects and Communication
O 4 credits 2G S. Goldhahn, T. Krones, B. Tag
Only for Human Medicine BSc

Abstract
The students develop the basics of medical law, clinical ethics and communication needed for central applications in the clinic. They learn which relevant legal framework conditions are to be observed in everyday clinical practice and how, in communication with patients, the principles of self-determination, patient well-being and damage avoidance are practically implemented.

Objective
After passing the modul sucessfully, students should be able to
- Know about ethical and legal basics of diagnostics and therapy and how these principles are put into practice
- Knowledge and use of central communication skills with patients, health care teams and the public
- Understand and describe the connections of ethics, law and communication and reflect on the implementation in clinical practice
- Apply the concept of evidence based decision aids
- Apply specific communication skills in simple clinical cases (informed consent, shared decision making, breaking bad news, communication of medical mistakes, Advance care Planning)
- Understand the concept and needs of vulnerable patients and address the concept ethically, legally and communicate adequately
- Know about the necessity of interprofessional collaboration in the process of dealing with ethically and juridically complex cases and practice first steps.

Content
- Overview of clinical ethical cases
- Basics in medical ethics and professional communication
- Knowledge and application of concepts as informed consent, possible alternative juridical instruments
- Knowledge and application of Shared decision Making
- Knowledge and application of advance care planning, concept of advance directives, treatment of patients incapable of decision making
- Breaking bad news, difficult prognoses
- Concept of vulnerability, special needs
- Differences of research/clinic, concept of evidence-based and presonalized medicine
- Conflicts of interests in therapy and research
- Basics on interprofessional cooperation in ethically and legally challenging situations
- Goal of care approach, dealing with end of life decisions
- Differential diagnoses and misdiagnosis, systems of avoidance of medical mistakes

Prerequisites / notice
Voraussetzungen:
- LE 377-0405-10L Ethik in Medizin und Gesundheitswesen
- Organsysteme der ersten vier Semester (Prüfungen absolviert)

377-0515-00L Patient Journeys
O 3 credits 3G C. Schlegel, E. Kut Bacs, G. Mang, T. Moser, P. Schütz, D. Stämpfli
Only for Human Medicine BSc

Abstract
The module deals with the importance of patient care by combining patient and interprofessional perspectives as well as the cooperation with other healthcare professions, at any moment (out- and inpatient treatment) as the patient progress along a care pathway.

Objective
- The students are able to analyze an interprofessional patient-path and modify it according to the personal patient situation.
- Students deal with other health professionals and together plan an appropriate patient-path.
- The students are able to take different perspectives (patient, family etc.) and consider them while planning a patient-path.
- Students actively participate in interprofessional sessions, are open to other viewpoints, and consider these for the care and safety of the patients.
Content

Based on various patient situations, students learn how an interprofessional patient-path looks like. During the self-study time, the students bring “their own patient” from their private environment and accompany her/him during the patient-path. Within this framework, the most important aspects will be documented and reflected. An exemplary patient case follows each session of the modules, to align the theoretical inputs with the corresponding patient case. In addition, together with pharmacy students, the students get to know the different roles in the pharmacy. In further sessions, the students learn which responsibilities, tasks and competences various health professionals have, during the care of the patients on their path. In addition, the students have the opportunity to visit a rural hospital in another canton and become acquainted with the importance of the free choice of doctors and treatments in other Cantons.

Prerequisites / notice

Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Homöostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

377-0501-00L Reproduction

Only for Human Medicine BSc

Abstract
In this module we lay the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and goes from the normal cycle of the woman and her disorders to the pregnancy and related issues to the obstetrics.

Objective

- Anatomy
  - Knowledge of the function of the female and male sexual organs
  - Explaining the development of the maternal and fetal parts of the placenta
  - Explaining the anatomy of the pelvis and the pelvic floor
- Gynecology
  - Recognizing gynecological emergencies
  - Listing of the various types of bleeding and irregularities
  - Overview of the benign tumors of the uterus and ovaries as well as the malignant tumors of the cervix and the endometrium
- Reproductive Endocrinology
  - Outlining of the main regulatory hormones of the female cycle and explaining their effects
  - Listing of the most important sterility factors
  - Discussing the main contraceptive methods with their mechanisms of action and contraceptive safety
- Physiological situations in obstetrics
  - Knowledge of the physiological processes and adaptation processes during pregnancy
  - Determination of birth process
  - Being aware of the meaning of the puerperium

Content
This module gives the anatomical and physiological foundations for the subject of "reproduction". The associated clinical challenges are conveyed from different points of view and with different actors. The content is chronologically prepared and shows the normal female cycle and her disorders as well as the pregnancy and related issues to the obstetrics. Students will have the opportunity to work with prospective midwives to learn basic skills of normal birth through a simulation.

Prerequisites / notice

Voraussetzungen:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Homöostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

377-0517-00L Oncology

Only for Human Medicine BSc

Abstract
Advances in our knowledge of cancer genetic and the cancer immunology are changing the ways by which clinicians treat various types of cancer. This is a unique course designed to help students to learn about cutting-edge principles of cancer genetic, cancer immunology and target therapy and to apply these concepts to the clinical practice guided by leading experts in the field.

Objective
Students will learn basic concepts of cancer patients' management and will acquired knowledge regarding experimental and clinically approved anti-cancer therapies.
Content

Basic knowledge in oncology
1. The cancer outbreak and its prevention
2. Tumor diagnostic, imaging and screening
3. Basic principle of cancer management and tumor recurrence
4. Clinical application: a clinical case study

Experimental immuno-oncology
1. Hallmarks of Cancer
2. The promise of Immuno-oncology
3. Experimental Immunotherapies: Checkpoint Blockade and CAR T cells
4. From Bedside to Bench to Bedside (Journal Club)

Targeted therapy
1. Cancer Genomics and Epigenomics
2. Basic knowledge of signal transduction and cancer metabolism
3. From Arsenic Trioxide and Glivec to modern targeted therapies
4. Mechanism of resistance to targeted therapies

Oncology practice
1. Basic and clinical application: Chemotherapy
2. Basic and clinical application: Radiotherapy
3. Clinical application: Evidence Based Medicine in oncology
4. Design and analysis of Clinical Trial
5. Clinical application: Immunotherapy
6. Clinical application: Target Therapy
7. From Symptoms to diagnosis
8. Oncology Emergency

Prerequisites / notice

Prerequisites:
LE 377-0105-00L Bewegungsapparat
LE 377-0107-00L Nervensystem
LE 377-0201-00L Herz-Kreislauf-System
LE 377-0203-00L Atmungs-System
LE 377-0205-00L Nieren und Homöostase
LE 377-0301-01L Blut, Immunsystem
LE 377-0301-02L Ernährung und Verdauung
LE 377-0301-03L Endokrinologie, Stoffwechsel
LE 377-0401-00L Sinnesorgane
LE 377-0403-00L Haut und Anhangsorgane

377-0519-00L Ultrasound Basics

O 1 credit 1P  M. Rominger

Only for Human Medicine BSc

Abstract
Zurich Ultrasound-Modell (ETH/SGUM/UZH) for ultrasound profiles (curricular) und SGUM certificate basic course abdomen during medical studies (SGUM-Young Sonographers, facultative) with E-Learning and 8 hours practical teaching with 4 students per machine and instructor (curricular), as well as facultative 8 more hours practice and OSCE in the following semester.

Objective

Ultrasound basics
- Understanding of basic ultrasound physics.
- Basic ultrasound anatomy abdomen.
- To know and to do a typical Abdomen and soft-tissue ultrasound examination.
- Classicual ultrasound pathology (Aszites, pleural effusion, gallstones, urinary retention ...).
- Know the most important artefacts and relevance for ultrasound imaging.
- SGUM basic abdomen certificate sucessful determination

Content

Modules curricular teaching ETHZ
- 1+2 Anatomy
- 3+4 Liver, biliary tract, pleura, rips, lung
- 5+6 Pankreas, spleen, adrenals, abdominal vessels
- 7+8 kidneys, bladder, neck, lumphnodes, FAST

SGUM – Young Sonographers (facultative in the 6th Semester BSc Human Medicine)
- 9+10
- 10+11
- 11+12
- 13+14

Prerequisites / notice

Ultrachall Theorie

Voraussetzung:
LE 377-0311-00L Praktikum klinische Anatomie

Courses in Medical Sciences

Core Courses 2nd Year

Number  Title  Type  ECTS  Hours  Lecturers
401-0683-00L  Statistics II  O  3 credits  2V+1U  D. Stekhoven

Abstract
Extension of statistics for medical students. This lecture is based on the content of Statistics I. The focus will be on the understanding and the concrete application of statistical methods, as they are used in medical research. Exercises will be solved using the statistical programming environment R.

Objective
After this course you will understand the concept of a broad selection of statistical methods (see also Content). Furthermore, you will know when to use which method. Especially, you will be able to read, understand, and scrutinise the results from such methods, whether these results are written or graphical. Using the statistical programming environment R, you will be able to read in data, analyse them in various ways, visualise and publish the results in reports or presentations. Knowing R will also enable you to reproduce published analyses, to check whether they work or to use them for your own medical research questions.
The course will cover the following topics. For the part on regression: simple linear regression; multiple regression (including factors and interactions); model selection; logistic regression (including odds ratio and their interpretation); Bayes inference. For the part on data: categorical data (including univariate tests); power analysis (including a guide on writing an ethics proposal); dealing with missing values.

For the part on further methods: supervised vs unsupervised learning; dimensional reduction (including PCA and ISNE); survival analysis (including Kaplan-Meier curves and logrank test).

There is no script.

An Introduction to Statistical Learning with Applications in R
Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani
Springer, 2013; online available from the ETH Library

Required: Statistics I

- **Core Courses 3rd Year**
  
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0866-00L</td>
<td>Foundations of Computer Science for Human Medicine BSc</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>H.-J. Böckenhauer, D. Komm</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This lecture gives an introduction to programming in Python and an overview of basic problem solving strategies and design principles for efficient algorithms and data structures.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>To learn basic principles of programming in Python and to apply them for implementing algorithmic approaches for solving simple computational problems.</td>
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<td><strong>Content</strong></td>
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<td>This lecture has two goals. On the one hand, an introduction to programming is given, using Python as a sample language. This introduction includes the basic programming principles such as truth values, variables, data types, conditional statements, loops, and functions. On the other hand, basic data structures (such as lists, stacks, and queues) and important concepts of algorithm design are presented and implemented in Python to efficiently solve basic algorithmic tasks on these data structures.</td>
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<td><strong>Lecture notes</strong></td>
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<td>All learning materials will be provided during the course.</td>
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<tr>
<td>377-0523-00L</td>
<td>Medical Technology I</td>
<td>O</td>
<td>3 credits</td>
<td>4G</td>
<td>O. Lambercy</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The course will guide students through the user-centered development and evaluation process of a medical engineering system for arm movement support. It will introduce the fundamentals of data acquisition, signal processing and control engineering, complemented by hands-on experience with sensors/signals, actuators, signal processing, feedforward/feedback control as well as 3D design/printing.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>The course enables students to:</td>
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<td>• prepare for the collaboration with engineers, and understand their approach to the analysis and characterization of technical challenges</td>
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<td>• describe the user-centered design and evaluation process of a medical engineering system</td>
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<td></td>
<td>• explain the fundamentals of data acquisition, signal processing and controls engineering</td>
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<td></td>
<td>• interpret measurements of physiological signals and analyze these for noise contributions</td>
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<td></td>
<td>• acquire practical experience with sensors/signals, actuators, signal processing, controls as well as 3D design/printing</td>
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<td><strong>Content</strong></td>
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<td>The course covers the interdisciplinary elements of a medical engineering development and its evaluation, ranging from human factors to sensor and actuator technologies, (real-time) signal processing, control engineering basics as well as safety/ethical aspects. It is framed around the electrophysiological assessment and robotic movement support following spinal cord injury, and complemented with practical training on a didactic elbow exoskeleton.</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td>Voraussetzungen:</td>
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<td>LE 402-0083-00L Physik I</td>
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<td>LE 402-0684-00L Physik II</td>
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<td><strong>Compensatory Courses</strong></td>
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<tr>
<td>376-0021-00L</td>
<td>Materials and Mechanics in Medicine</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Zenobi-Wong, J. G. Snedeker</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.</td>
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<td><strong>Objective</strong></td>
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<td></td>
<td>Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.</td>
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<td><strong>Content</strong></td>
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<td>Biomaterials, Tissue Engineering, Tissue Biomechanics, Implants.</td>
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<td><strong>Lecture notes</strong></td>
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<td>course website on Moodle</td>
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<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4 credits</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.</td>
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</table>
Objective: Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content: Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived. In the final discussions on biomedical applications and potential health risk issues, scientific aspects as well as the many of the emerging materials will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes: All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Level</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>4</td>
<td>W</td>
<td>K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
</tr>
<tr>
<td>376-1651-00L</td>
<td>Clinical and Movement Biomechanics</td>
<td>4</td>
<td>G</td>
<td>N. Singh, R. List, P. Schütz</td>
</tr>
<tr>
<td>535-0022-00L</td>
<td>Computer-Assisted Drug Design</td>
<td>1</td>
<td>V</td>
<td>S. Liniker, G. Landrum</td>
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<tr>
<td>535-0250-00L</td>
<td>Biotransformation of Drugs and Xenobiotics</td>
<td>1</td>
<td>V</td>
<td>S.-D. Krämer</td>
</tr>
</tbody>
</table>

Literature: Handouts and references therein.

Number of participants limited to 50.

Literature:
  (available online via ETH library)

Literature:

Lecture notes:
- Handouts are deposited online (moodle).
- Literature: Recommended textbooks:
**535-0310-00L**

**Glycobiology in Drug Development**

**W** 1 credit 1V V. I. Otto

**Abstract**
Protein-based drugs constitute around 25% of new approvals and most of them are glycoproteins. Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

**Objective**
Students gain basic knowledge in “pharmaceutical glycobiology”. This implies knowing and understanding:
- major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- the major types of protein-linked glycans and the biosynthetic pathways for their formation
- how glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper).

Students gain the ability to reflect on roles of glycosylation in various biological contexts.

**Content**
lecture plan:
1. Glycans - information carriers in biology and pharmatherapy
2. Glucocerebrosidase and the biosynthesis of N-glycans
3. Improving the therapeutic profile of monoclonal antibodies by glycoengineering
4. Mucin-type O-glycans and sialylation as gCQA of glycoprotein hormone drugs
5. Production and gCQA analysis of Glucocerebrosidase, monoclonal antibodies, glycoprotein hormone drugs - Glycoanalytics
6. EPO “the same but different”

**Lecture notes**
The slides used for the lectures will be provided online

**Literature**
- recent publications as cited/proposed on the lecture slides

**Prerequisites / requirements**
Basic knowledge in immunology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

---

**535-0423-00L**

**Drug Delivery and Drug Targeting**

**W** 2 credits 1.5V J.-C. Leroux, A. Steinauer

**Abstract**
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

**Objective**
The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

**Content**
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

**Lecture notes**
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

**Literature**


Further references will be provided in the course.

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**551-0307-00L**

**Molecular and Structural Biology I: Protein Structure and Function**

**W** 3 credits 2V R. Glockshuber, K. Locher, E. Weber-Ban

*D-BIOL students are obliged to take part I and part II (next semester) as a two-semester course*

**Abstract**
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

551-0309-00L Concepts in Modern Genetics

Information for UZH students: Enrolment to this course unit only possible at ETH. No enrolment to module BIC348 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract
Concepts of modern genetics and genomics, including principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Objective
This course focuses on the concepts of classical and modern genetics and genomics.

Content
The topics include principles of classical genetics; yeast genetics; gene mapping; forward and reverse genetics; structure and function of eukaryotic chromosomes; molecular mechanisms and regulation of transcription, replication, DNA repair and recombination; analysis of developmental processes; epigenetics and RNA interference.

Lecture notes
Scripts and additional material will be provided during the semester.

551-0313-00L Microbiology (Part I)

Abstract
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Objective
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Content
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

Lecture notes
Updated handouts will be provided during the class.

Literature
Current literature references will be provided during the lectures.

Prerequisites / notice
English
The lecture “Grundlagen der Biologie II: Mikrobiologie” is the basis for this advanced lecture.

551-0319-00L Cellular Biochemistry (Part I)

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

701-2413-00L Evolutionary Genetics

Abstract
The concept course ‘Evolutionary Genetics’ consists of two lectures that jointly provide an introduction to the fields of population and quantitative genetics (emphasis on basic concepts) and ecological genetics (more emphasis on evolutionary and ecological processes of adaptation and speciation).

Objective
The aim of the course is to provide students with a solid introduction to the fields of population genetics, quantitative genetics, and ecological genetics. The concepts and research methods developed in these fields have undergone profound transformations; they are of fundamental importance in our understanding of evolutionary processes, both past and present. Students should gain an appreciation for the concepts, methods and explanatory power of evolutionary genetics.

Content
Population genetics - Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory. Quantitative genetics - Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher’s fundamental theorem. Ecological Genetics - Concepts and methods for the study of genetic variation and its role in adaptation, reproductive isolation, hybridization and speciation.

Lecture notes
Handouts

Literature

752-4009-00L Molecular Biology of Foodborne Pathogens

Abstract
The full-year course (551-0313-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of the cell, providing advanced insights into structure, function and regulatory processes of individual cell components, regulation of their interactions, and various aspects of the regulatory and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Objective
The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.

Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.
Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophages for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

Human Medicine Bachelor - Key for Type

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

Special students and auditors need special permission from the lecturers.
Computer Science (General Courses)

Computer Science for Non-Computer Scientists

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0834-00L</td>
<td>Information Systems for Engineers</td>
<td>Z</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>G. Fourny</td>
</tr>
</tbody>
</table>

Abstract

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL
6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage
11. Analytics on top of a relational database
12. Data cubes

Taking a relational database to the next level

13. Outlook
- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only. BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0836-00L</td>
<td>Computer Science II</td>
<td>Z</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Schwerhoff, F. O. Friedrich Wicker</td>
</tr>
</tbody>
</table>

Abstract

The course provides the foundations for the design and analysis of algorithms. Classical problems ranging from sorting up to problems on graphs are used to discuss common data structures, algorithms and algorithm design paradigms.

The course also comprises an introduction to parallel and concurrent programming.

Objective

An understanding of the analysis and design of fundamental and common algorithms and data structures. Knowledge regarding chances, problems and limits of parallel and concurrent programming.
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects.

English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online. All required mathematical tools above high school level are covered, including a introduction to graph theory.

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Literature</th>
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</thead>
<tbody>
<tr>
<td>252-0851-00L Algorithms and Complexity</td>
<td>R. Sasse, F. O. Friedrich Wicker</td>
</tr>
<tr>
<td>252-0852-00L Foundations of Computer Science</td>
<td>L. E. Fässler, M. Dahinden</td>
</tr>
</tbody>
</table>

The following topics are covered: modeling and simulations, introduction to programming, introduction matrices, managing data with lists and tables and with relational databases, introduction to programming.

Data structures and algorithms: mathematical tools for the analysis of algorithms (asymptotic function growth, recurrence equations, recurrence trees), informal proofs of algorithm correctness (invariants and code transformation), design paradigms for the development of algorithms (induction, divide-and-conquer, backtracking and dynamic programming), classical algorithmic problems (searching, selection and sorting), data structures for different purposes (linked lists, hash tables, balanced search trees, heaps, union-find), further tools for runtime analysis (generating functions, amortized analysis). The relationship and tight coupling between algorithms and data structures is illustrated with graph algorithms (traversals, topological sort, closure, shortest paths, minimum spanning trees).

Parallel programming: structure of parallel architectures (multicore, vectorization, pipelining) concepts of parallel programming (Amdahl's and Gustavson's laws, task/data parallelism, scheduling), problems of concurrency (data races, bad interleavings, memory reordering), process synchronisation and communication in a shared memory system (mutual exclusion, semaphores, monitors, condition variables).

In general, the concepts provided in the course are motivated and illustrated with practically relevant algorithms and applications.

Exercises are carried out in Code-Expert, an online IDE and exercise management system.

All required mathematical tools above high school level are covered, including a introduction to graph theory.

Prerequisite: Computer Science I

252-0839-00L Informatics

Objective
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

Content
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to macro programming
5. Introduction to programming with Python

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

252-0845-00L Computer Science I

Objective
Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs.

Content
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to macro programming

Lecture notes
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

252-0847-00L Computer Science

Objective
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens “behind the scenes” when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture notes
English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.

252-0851-00L Algorithms and Complexity

Objective
After this course students know some basic algorithms as well as underlying paradigms. They will be familiar with basic notions of complexity theory and can use them to classify problems.

Content

Lecture notes
Ja.

252-0852-00L Foundations of Computer Science

Objective
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects.

The following topics are covered: modeling and simulations, introduction to programming, introduction matrices, managing data with lists and tables and with relational databases, universal methods for algorithm design.


Autumn Semester 2021
The students learn to:
- understand the role of computer science in science,
- to control computer and automate processes of problem solving by programming,
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

1. The role of computer science in science
2. Introduction to Programming with Python
3. Modeling and simulations
4. Data management with lists and tables
5. Data management with a relational database
6. Introduction to Matrices

This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

Domain A - Subject-specific Competencies
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: not assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

Domain C - Social Competencies
- Communication: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

The unit "Computer Science in Secondary School Mathematics" addresses key contributions of computer science to general education, the tight relations between the algorithmic and the mathematical way of thinking, and the thoughtful choice of computer science topics for high school mathematics classes.

The general goal of the course consists in presenting ways to teach fundamentals of computer science, which are closely related to contents and methods of mathematics. After attending the course unit, a mathematics teacher is able to teach selected fundamentals of computer science in mathematics classes.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The course covers the didactics of logic, of cryptography, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value for mathematics classes.

The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.
Objective

Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content

The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture notes

English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.

Literature

Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

> Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>251-0100-00L</td>
<td>Computer Science Colloquium</td>
<td>E</td>
<td>0 credits</td>
<td>2K</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Invited talks, covering the entire scope of computer science. External Listeners are welcome at no charge. A detailed schedule is published at the beginning of each semester.</td>
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<tr>
<td>Objective</td>
<td>Top international computer scientists take the floor at the distinguished computer science colloquium. Our guest speakers present impacting topics across various areas of the discipline. The colloquium series is held every semester and also includes inaugural and farewell lectures of the department's professors. The colloquium is a noteworthy event for all graduate students. Outside attendance is equally welcome.</td>
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<tr>
<td>Content</td>
<td>Eingeladene Vorträge aus dem gesamten Bereich der Informatik, zu denen auch Auswärtige kostenlos eingeladen sind. Zu Semesterbeginn erscheint jeweils ein ausführliches Programm.</td>
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<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and Education</td>
<td>E</td>
<td>0 credits</td>
<td>N. Hungerbühler, M. Akveld, D. Grawehr Morath, J. Hromkovic, P. Spindler</td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Didactics colloquium</td>
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<tr>
<td>Subject</td>
<td>didactics for mathematics and computer science teachers.</td>
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</table>

Computer Science (General Courses) - Key for Type

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

Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Computer Science Bachelor

First Year Examinations

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0025-01L</td>
<td>Discrete Mathematics</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>U. Maurer</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td>Content</td>
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<td>Objective</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td>252-0027-00L</td>
<td>Introduction to Programming</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>T. Gross</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Content</td>
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<td>Lecture notes</td>
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</table>

Discrete Mathematics

Content: Mathematical reasoning and proofs, abstraction. Sets, relations (e.g. equivalence and order relations), functions, (un-)countability, number theory, algebra (groups, rings, fields, polynomials, subalgebras, morphisms), logic (propositional and predicate logic, proof calculi).

Objective: The primary goals of this course are (1) to introduce the most important concepts of discrete mathematics, (2) to understand and appreciate the role of abstraction and mathematical proofs, and (3) to discuss a number of applications, e.g. in cryptography, coding theory, and algorithm theory.

Introduction to Programming

Abstract: Introduction to fundamental concepts of modern programming and operational skills for developing high-quality programs, including large programs as in industry. The course introduces computer engineering principles with an object-oriented approach based.

Objective: Many people can write programs. The "Introduction to Programming" course goes beyond that basic goal: it teaches the fundamental concepts and skills necessary to perform programming at a professional level. As a result of successfully completing the course, students master the fundamental control structures, data structures, reasoning patterns and programming language mechanisms characterizing modern programming, as well as the fundamental rules of producing high-quality software. They have the necessary programming background for later courses introducing programming skills in specialized application areas.

Content: Basics of object-oriented programming, Objects and classes, Pre- and postconditions, class invariants, design by contract. Fundamental control structures. Assignment and references. Fundamental data structures and algorithms. Recursion. Inheritance and interfaces, basic concepts of Software Engineering such as the software process, specification and documentation, debugging, reuse and quality assurance.

Algorithms and Data Structures

Abstract: The course provides the foundation of the design and analysis of algorithms. The material is introduced using classical algorithmic problems including graph problems. The necessary basic introduction to graph theory is provided as part of this course.

Objective: An understanding of the design and analysis of fundamental algorithms and data structures. A basic understanding of graph theory and several basic graph algorithms.

Content: This course is an introduction into the design and analysis of algorithms. On the one hand this includes classical algorithm design patterns including induction, divide-and-conquer and dynamic programming. We study these using classical example such as searching and sorting. On the other hand the course covers the interaction between algorithms and data structures including linked lists, search trees, heaps, and union-find structures. A particular focus are graph algorithms for shortest path and minimal spanning tree problems. We provide the necessary introduction into graph theory as part of this course.

Linear Algebra

Abstract: Introduction to linear algebra (vector spaces, linear transformations, matrices), inner product, determinants, matrix decompositions (LU, QR, eigenvalue and singular value decomposition).

Objective: - Understand and apply fundamental concepts of linear algebra
           - Learn about applications of linear algebra

Content: Linear Algebra:

- Linear systems of equations, vectors and matrices, norms and scalar products, LU decomposition, vector spaces and linear transformations, least squares problems, QR decomposition, determinants, eigenvalues and eigenvectors, singular value decomposition, applications.

Theoretical Computer Science

Abstract: Concepts to cope with: a) what can be accomplished in a fully automated fashion (algorithmically solvable) b) How to measure the inherent difficulty of tasks (problems) c) What is randomness and how can it be useful? d) What is nondeterminism and what role does it play in CS? e) How to represent infinite objects by finite automata and grammars?

Objective: Learning the basic concepts of computer science along their historical development

Basic Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0131-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>O. Imamoglu, O. Sorkine Hornung</td>
</tr>
<tr>
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<td>Abstract</td>
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This lecture gives an introduction to theoretical computer science, presenting the basic concepts and methods of computer science in its historical context. We present computer science as an interdisciplinary science which, on the one hand, investigates the border between the possible and the impossible and the quantitative laws of information processing, and, on the other hand, designs, analyzes, verifies, and implements computer systems.

The main topics of the lecture are:
- alphabets, words, languages, measuring the information content of words, representation of algorithmic tasks
- finite automata, regular and context-free grammars
- Turing machines and computability
- complexity theory and NP-completeness
- design of algorithms for hard problems

The lecture is covered in detail by the textbook "Theoretical Computer Science".

Basic literature:

Further reading:

More exercises and examples in:
6. A. Asteroth, Ch. Baier: Theoretische Informatik

Prerequisites / notice
During the semester, two non-obligatory test exams will be offered.

252-0061-00L Systems Programming and Computer Architecture O 7 credits 4V+2U T. Roscoe, A. Klimovic

Abstract
Introduction to systems programming. C and assembly language, floating point arithmetic, basic translation of C into assembler, compiler optimizations, manual optimizations. How hardware features like superscalar architecture, exceptions and interrupts, caches, virtual memory, multicore processors, devices, and memory systems function and affect correctness, performance, and optimization.

Objective
The course objectives are for students to:

1. Develop a deep understanding of, and intuition about, the execution of all the layers (compiler, runtime, OS, etc.) between programs in high-level languages and the underlying hardware: the impact of compiler decisions, the role of the operating system, the effects of hardware on code performance and scalability, etc.

2. Be able to write correct, efficient programs on modern hardware, not only in C but high-level languages as well.

3. Understand Systems Programming as a complement to other disciplines within Computer Science and other forms of software development.

This course does not cover how to design or build a processor or computer.

Content
This course provides an overview of "computers" as a platform for the execution of (compiled) computer programs. This course provides a programmer's view of how computer systems execute programs, store information, and communicate. The course introduces the major computer architecture structures that have direct influence on the execution of programs (processors with registers, caches, other levels of the memory hierarchy, supervisor/kernel mode, and I/O structures) and covers implementation and representation issues only to the extend that they are necessary to understand the structure and operation of a computer system.

The course attempts to expose students to the practical issues that affect performance, portability, security, robustness, and extensibility. This course provides a foundation for subsequent courses on operating systems, networks, compilers and many other courses that require an understanding of the system-level issues. Topics covered include: machine-level code and its generation by optimizing compilers, address translation, input and output, trap/event handlers, performance evaluation and optimization (with a focus on the practical aspects of data collection and analysis).
### Lecture notes
- C programming
- Integers
- Pointers and dynamic memory allocation
- Basic computer architecture
- Compiling C control flow and data structures
- Code vulnerabilities
- Implementing memory allocation
- Linking
- Floating point
- Optimizing compilers
- Architecture and optimization
- Caches
- Exceptions
- Virtual memory
- Multicore
- Devices

### Literature
The course is based in part on "Computer Systems: A Programmer's Perspective" (3rd Edition) by R. Bryant and D. O'Hallaron, with additional material.

### Prerequisites / notice
- 252-0029-00L Parallel Programming
- 252-0028-00L Design of Digital Circuits

<table>
<thead>
<tr>
<th>Module</th>
<th>Title</th>
<th>Credits</th>
<th>Hours</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0213-15L</td>
<td>Analysis II</td>
<td>O</td>
<td>5</td>
<td>M. Burger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Differential and integral calculus in many variables, vector analysis.</td>
<td></td>
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<tr>
<td>Literature</td>
<td>Für allgemeine Informationen, sehen Sie bitte die Webseite der Vorlesung</td>
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<tr>
<th>Module</th>
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<tbody>
<tr>
<td>401-0663-00L</td>
<td>Numerical Methods for Computer Science</td>
<td>O</td>
<td>7</td>
<td>R. Hiptmair</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.</td>
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</tbody>
</table>
| Objective         | * Knowledge of the fundamental algorithms in numerical mathematics  
                  |        |       |                |
|                   |   * Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms  
                  |        |       |                |
|                   |   * Ability to choose the appropriate numerical method for concrete problems  
                  |        |       |                |
|                   |   * Ability to interpret numerical results  
                  |        |       |                |
|                   |   * Ability to implement numerical algorithms efficiently  
                  |        |       |                |
| Content           | * Computing with Matrices and Vectors  
                  |        |       |                |
|                   |   2.1 Fundamentals  
                  |        |       |                |
|                   |   2.2 Software and Libraries  
                  |        |       |                |
|                   |   2.4 Computational Effort  
                  |        |       |                |
|                   |   2.5 Machine Arithmetic and Consequences  
                  |        |       |                |
|                   | * Direct Methods for (Square) Linear Systems of Equations  
                  |        |       |                |
|                   |   3.1 Introduction: Linear Systems of Equations (LSE)  
                  |        |       |                |
|                   |   3.2 Theory: Linear Systems of Equations (LSE)  
                  |        |       |                |
|                   |   3.5 Survey: Elimination Solvers for Linear Systems of Equations  
                  |        |       |                |
|                   |   3.7 Sparse Linear Systems  
                  |        |       |                |
|                   | * Direct Methods for Linear Least Squares Problems  
                  |        |       |                |
|                   |   4.1 Least Squares Solution Concepts  
                  |        |       |                |
|                   |   4.2 Normal Equation Methods  
                  |        |       |                |
|                   |   4.3 Orthogonal Transformation Methods  
                  |        |       |                |
|                   |   4.3.1 Transformation Idea  
                  |        |       |                |
|                   |   4.3.2 Orthogonal/Unitary Matrices  
                  |        |       |                |
|                   |   4.3.3 QR-Decomposition  
                  |        |       |                |
|                   |   4.3.4 QR-Based Solver for Linear Least Squares Problems  
                  |        |       |                |
|                   |   4.4 Singular Value Decomposition (SVD)  
                  |        |       |                |
|                   |   4.5 SVD-Based Optimization and Approximation  
                  |        |       |                |
|                   | * Filtering Algorithms  
                  |        |       |                |
|                   |   5.1 Filters and Convolutions  
                  |        |       |                |
|                   |   5.2 Discrete Fourier Transform (DFT)  
                  |        |       |                |
|                   |   5.3 Fast Fourier Transform (FFT)  
                  |        |       |                |
|                   | * Machine Learning of One-Dimensional Data (Data Interpolation and Data Fitting in 1D)  
                  |        |       |                |
|                   |   6.1 Abstract Interpolation (AI)  
                  |        |       |                |
|                   |   6.2 Global Polynomial Interpolation  
                  |        |       |                |
|                   |   6.4 Splines  
                  |        |       |                |
|                   |   6.7 Least Squares Data Fitting  
                  |        |       |                |
|                   | * Iterative Methods for Non-Linear Systems of Equations  
                  |        |       |                |
|                   |   9.2 Iterative Methods  
                  |        |       |                |
|                   |   9.4 Finding Zeros of Scalar Functions  
                  |        |       |                |
|                   |   9.5 Newton's Method in R^n  
                  |        |       |                |
|                   |   9.7 Non-linear Least Squares  
                  |        |       |                |

Lecture notes: Lecture materials (PDF documents and codes) will be made available to the participants through the course web page and online repositories. Access information will be communicated in the beginning of the course.
Learn principles of compiler design; gain practical experience designing and implementing a medium-scale software system.


S. Coros

A scriptum will be handed out for a part of the course. Copies of the slides will be available for download. We will also provide a detailed list of references and textbooks.

This course uses compilers as example to expose modern software development techniques. The course introduces the students to the common theoretical results, practical tradeoffs, and design principles that apply across many different scales and technologies. Large-scale distributed systems that power today's online services. We illustrate the ideas with real-world examples, but emphasize the underlying principles.

Prerequisites:
- A tentative list of topics: compiler organization; lexical analysis; top-down and bottom-up parsing; symbol tables; semantic analysis; code generation; register allocation; automatic memory management.
- Students will learn the use of appropriate tools. Throughout the course, students learn to apply their knowledge of theory (automata, grammars, stack machines, program transformation) and well-known programming techniques (module definitions, design patterns, frameworks, software reuse) in a software project.

Objective:
- Learn principles of compiler design; gain practical experience designing and implementing a medium-scale software system.

Content:
- This course uses compilers as example to expose modern software development techniques. The course introduces the students to the fundamentals of compiler construction. Students will implement a simple yet complete compiler for an object-oriented programming language for a realistic target machine. Students will learn the use of appropriate tools. Throughout the course, students learn to apply their knowledge of theory (automata, grammars, stack machines, program transformation) and well-known programming techniques (module definitions, design patterns, frameworks, software reuse) in a software project.

Literature:
- Prerequisites:
  - Prior exposure to modern techniques for program construction, knowledge of at least one processor architecture at the assembly language level.

Prerequisites:
- Prerequisites:
  - Prior exposure to modern techniques for program construction, knowledge of at least one processor architecture at the assembly language level.
Objective

The objective of the course is for students to understand the theoretical principles, practical considerations, performance tradeoffs, and engineering techniques on which the software underpinning almost all modern computer systems is based, ranging from single embedded systems-on-chip in mobile phones to large-scale geo-replicated groups of datacenters.

By the end of the course, students should be able to reason about highly complex, real, operational software systems, applying concepts such as hierarchy, modularity, consistency, durability, availability, fault-tolerance, and replication.

Content

This course subsumes the topics of both "operating systems" and "distributed systems" into a single coherent picture (reflecting the reality that these disciplines are highly converged). The focus is system software: the foundations of modern computer systems from mobile phones to the large-scale geo-replicated data centers on which Internet companies like Amazon, Facebook, Google, and Microsoft are based.

We will cover a range of topics, such as: scheduling, network protocol stacks, multiplexing and demultiplexing, operating system structure, inter-process communication, memory management, file systems, naming, dataflow, data storage, persistence, and durability. computer systems performance, remove procedure call, consensus and agreement, fault tolerance, physical and logical clocks, virtualization, and blockchains.

The format of the course is a set of about 25 topics, each covered in a lecture. A script will be published online ahead of each lecture, and the latter will consist of an interactive elaboration of the material in the script. There is no book for the course, but we will refer to books and research papers throughout to provide additional background and explanation.

Prerequisites / notice

We will assume knowledge of the "Systems Programming" and "Computer Networks" courses (or equivalent), and their prerequisites, and build upon them.

Electorics

Students may also choose courses from the Master's program in Computer Science. It is their responsibility to make sure that they meet the requirements and conditions for these courses.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0293-00L</td>
<td>Wireless Networking and Mobile Computing</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>S. Mangold</td>
</tr>
</tbody>
</table>

Abstract

This course gives an overview about wireless standards and summarizes the state-of-art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, including new topics such as contact tracing with Bluetooth, audio communication, cognitive radio, visible light communications. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool.

Objective

The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication.

Content

New: Starting 2020, we will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth.

Lecture notes

The course material will be made available by the lecturer.

Literature

(1) The course webpage (look for Stefan Mangold's site)
(2) The Java 802 protocol emulator "JEmula802" from https://bitbucket.org/lfield/jemula802

Prerequisites / notice

Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).

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<tbody>
<tr>
<td>252-3110-00L</td>
<td>Human Computer Interaction</td>
<td>W</td>
<td>6</td>
<td>2V+1U+2A</td>
<td>O. Hilliges, C. Holz</td>
</tr>
</tbody>
</table>

Abstract

The course provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

Objective

The goal of the course is that students should understand the principles of user-centred design and be able to apply these in practice. As well understand the basic notions of Computational Design in a HCI context.

Content

The course will introduce students to various methods of analysing the user experience, showing how these can be used at different stages of system development from requirements analysis through to usability testing. Students will get experience of designing and carrying out user studies as well as analysing results. The course will also cover the basic principles of interaction design. Practical exercises related to touch and gesture-based interaction will be used to reinforce the concepts introduced in the lecture. To get students to further think beyond traditional system design, we will discuss issues related to ambient information and awareness.

The course website can be found here: https://teaching.siplab.org/human_computer_interaction/2021/

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<th>ECTS</th>
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<th>Lecturers</th>
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Abstract

This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

Objective

With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.
Content

1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)

2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)

3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models

4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

Lecture notes

https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/

Class notes, handouts

Literature

- An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann
- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Computer Organization and Design, D.H. Patterson and J.L. Henessy, Morgan Kaufmann
- Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press
- Lecture notes

Prerequisites / notice

Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

227-0124-00L Embedded Systems W 6 credits 4G L. Thiele, M. Magno

Abstract

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.

Objective

Understanding specific requirements and problems arising in embedded system applications.

Content

Understanding architectures and components, their hardware-software interfaces, the memory architecture, communication between components, embedded operating systems, real-time scheduling theory, shared resources, low-power and low-energy design as well as hardware architecture synthesis.

Using the formal models and methods in embedded system design in practical applications using the programming language C, the operating system FreeRTOS, a commercial embedded system platform and the associated design environment.

Specifically the following topics will be covered in the course: Embedded system architectures and components, hardware-software interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.

More information is available at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Lecture notes

The following information will be available: Lecture material, publications, exercise sheets and laboratory documentation at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Literature


Prerequisites / notice

Prerequisites: Basic knowledge in computer architectures and programming.

227-1037-00L Introduction to Neuroinformatics W 6 credits 2V+1U+1A V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens

Abstract

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Objective

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, math, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.
Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

Quantum Physics for Non-Physicists

W 6 credits 3V+2U L. Pacheco Cañamero B. del Rio

Abstract
This is an introduction to the physics of quantum mechanics, aimed primarily at students with little to no background in physics. We start from the basic postulates and follow an information-theoretical approach to study the behaviour of quantum systems, from a single spin to entangled particles in space and the hydrogen atom.

Objective
This course teaches the basics of quantum physics, and complements courses in quantum computation and information theory. Students are equipped with tools to tackle complex quantum mechanical problems and foundational questions. The course covers approximately the same content as QM1, but from an information-driven perspective.

Content
1. Quantum formalism, from qubits to particles in space
2. Time and dynamics for quantum systems
3. Problems in 1D
4. Uncertainty and open systems
5. Spin
6. Problems in 3D
7. Non-locality and foundational aspects of quantum theory

Lecture notes
Lecture notes will be distributed through the semester.

Literature
Quantum Processes Systems, and Information, by Benjamin Schumacher and Michael Westmoreland, available at https://www.cambridge.org/core/books/quantum-processes-systems-and-information/4E459E64E1EE7121CA2321435FAECC8A

Prerequisites / notice
This course is aimed at non-physicists, and in particular at students with a background in computer science, mathematics or engineering. Basic linear algebra and calculus knowledge is required (equivalent to first-year courses). Physics knowledge is not required. Physicists and students from a different background than outlined above are welcome at their own risk.

Note that while we follow an information-theoretical approach, this is not a course on quantum information theory or quantum computing. It therefore complements those courses offered at ETH in both semesters.

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making not assessed
Media and Digital Technologies not assessed
Problem-solving assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management assessed

Seminar

Number Title Type ECTS Hours Lecturers
252-2300-00L Dependency Structures and Lexicalized Grammars W 2 credits 2S R. Cotterell

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Number of participants limited to 25.

Abstract
Dependency parsing is a fundamental task in natural language processing. This seminar explores a variety of algorithms for efficient dependency parsing and their derivation in a unified algebraic framework.

Objective
The core ideas behind the mathematics of dependency parsing are explored.

Content
Dependency Structures and Lexicalized Grammars: An Algebraic Approach

Seminar on Media Innovation

The technical content of this course falls into the general area of software engineering but will vary from semester to semester.

The main goals of this seminar are 1) learning how to read and understand a recent research paper in computer science; and 2) learning how to present a technical topic in computer science to an audience of peers.

Seminar on Machine Learning Systems

This seminar covers core concepts and ideas in the general area of machine learning systems, ranging from distributed and federated learning systems, DevOps systems for ML, life cycle and data management systems for ML, etc.

Objective

The seminar covers core concepts and ideas in the general area of machine learning systems, ranging from distributed and federated learning systems, DevOps systems for ML, life cycle and data management systems for MLs, etc. The focus will be to cover fundamental ideas on ML systems, with an emphasis on software systems and platforms.

Content

The seminar will consist of student presentations based on a list of papers that will be provided at the beginning of the course. Presentations will be done in teams. Presentations will be arranged in slots of 30 minutes talk plus 15 minutes questions. Grades will be assigned based on quality of the presentation, coverage of the topic including material not in the original papers, participation during the seminar, and ability to understand, present, and criticize the underlying technology.

Case Studies from Practice Seminar

Participants will learn how to analyze and solve IT problems in practice in a systematic way, present findings to decision bodies, and defend their conclusions.

Objective

Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

Content

Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to company representatives, the lecturer, and all other participants of the seminar. Participants also learn how to challenge presentations from other teams, and obtain an overview of learnings from the cases other teams worked on.

Lecture notes

Methodologies to analyze the cases and create final presentations. Short overview of each case.

Prerequisites / notice

Successful completion of Lecture "Case Studies from Practice".
Content

The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous

ECTS

Concepts and Theories

M. H. K. Alser,

Hours


2 credits

O. Mutlu, M. H. K. Alser,

Analytical Competencies

J. Gómez Luna

Abstract

In this seminar course, we will cover fundamental and cutting-edge research papers in computer architecture. The course will consist of multiple components that are aimed at improving students’ technical skills in computer architecture, critical thinking and analysis on computer architecture concepts, as well as technical presentation of concepts and papers in both spoken and written forms.

Objective

The main objective is to learn how to rigorously analyze and present papers and ideas on computer architecture. We will have rigorous presentation and discussion of selected papers during lectures and a written report delivered by each student at the end of the semester.

Content

This course is for those interested in computer architecture. Registered students are expected to attend every lecture, participate in the discussion, and create a synthesis report at the end of the course.

Lecture notes

All the materials will be posted on the course website: https://safari.ethz.ch/architecture_seminar/

Links to past course materials, including the synthesis report assignment, can be found in this page:

https://safari.ethz.ch/architecture_seminar/doku.php?id=sidebar

Literature

Key papers and articles, on both fundamentals and cutting-edge topics in computer architecture will be provided and discussed. These will be posted on the course website.

Prerequisites / notice

Students should have done very well in Design of Digital Circuits and show a genuine interest in Computer Architecture.

► Minor Courses

➤ 3. Semester

Number

Title

Type

ECTS

Hours

Lecturers

227-0945-00L

Cell and Molecular Biology for Engineers I

W

3 credits

2G

C. Frei

This course is part I of a two-semester course.

Abstract

The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Objective

After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content

Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication. These written documents will be graded and count as 40% for the final grade.

Lecture notes

Scripts of all lectures will be available.

Literature


Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

assessed

Techniques and Technologies

assessed

Analytical Competencies

assessed

Decision-making

assessed

Media and Digital Technologies

assessed

Problem-solving

assessed

Problem Management

assessed

Domain B - Method-specific Competencies

Communication

assessed

Cooperation and Teamwork

assessed

Customer Orientation

assessed

Leadership and Responsibility

assessed

Self-presentation and Social Influence

assessed

Sensitivity to Diversity

assessed

Negotiation

assessed

Domain C - Social Competencies

Adaptability and Flexibility

assessed

Creative Thinking

assessed

Critical Thinking

assessed

Integrity and Work Ethics

assessed

Self-awareness and Self-reflection

assessed

Self-direction and Self-management

assessed

351-0778-00L

Discovering Management

W

3 credits

3G

B. Clarysse, S. Brusoni, E. Fleisch,

G. Grote, V. Hoffmann, T. Netland,

Y. R. Shrestha, P. Tinguely,

L. P. T. Vandeweghe

Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering
Management (Exercises) 351-0778-01.

Abstract
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

Objective
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

These course materials will form the point of departure for the lectures, class discussions and team work.

Taught competencies

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351-0778-01L
Discovering Management (Exercises)
Complementary exercises for the module Discovering Management.

Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

Abstract
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

Objective
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Content
Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management.

Students have the option to either write this alone or in a group of two students.

Literature
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

Taught competencies

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376-1177-00L
Human Factors I

Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.

Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Broucheures, checklists, key articles etc. are uploaded in ILIAS
Computational Astrophysics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: AST245

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cms/ssl/en/studies/application/deadlines.html

Objective

Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programs.

Content

1. Integration of ODE, Hamiltonians and Symplectic integration techniques, time adaptivity, time reversibility
2. Large-N gravity calculation, collisionless N-body systems and their simulation
3. Fast Fourier Transform and spectral methods in general
4. Eulerian Hydrodynamics: Upwinding, Riemann solvers, Limiters
5. Lagrangian Hydrodynamics: The SPH method
6. Resolution and instabilities in Hydrodynamics
7. Initial Conditions: Cosmological Simulations and Astrophysical Disks
8. Physical Approximations and Methods for Radiative Transfer in Astrophysics

Literature

Galactic Dynamics (Binney & Tremaine, Princeton University Press),
Computer Simulation using Particles (Hockney & Eastwood CRC press),
Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh)

Prerequisites

Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial.

Data Analysis and Visualisation with Matlab in Earth Sciences

Information for D-INFK students: the course is only for 3rd semester BSc students.

Objective

The following concepts are introduced in the course:
- Working with matrices and arrays
- Programming and development of algorithms
- Effective data analysis and visualisation in 2D and 3D
- Learning to effectively use animations
- Statistical description of a dataset
- Regression analysis
- Testing hypotheses

Abstract

This lecture and the corresponding exercises provide the students with an introduction to the concepts and tools of scientific data analysis. Based on current questions in the Earth Sciences, the students solve problems of increasing complexity both in small groups and singly using the software package MATLAB. Students also learn how to effectively visualise different kinds of datasets.

Mathematics III: Systems Analysis

Abstract

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

Objective

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

Content

https://iac.etzb.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html

Lecture notes

Overhead slides will be made available through the course website.

Literature


Solving Partial Differential Equations in parallel on GPUs

This course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

Objective

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

5. Semester
Part 1 - Discovering a modern parallel computing ecosystem
- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

Part 2 - Developing your own parallel algorithms
- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

Part 3 - Final project
- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

Lecture notes
Digital lecture notes, interactive Julia notebooks, exam material.

Literature
Links to relevant literature will be provided during classes.

Prerequisites / notice
Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

102-0227-00L Systems Analysis and Mathematical Modeling in Urban Water Management

Number of participants limited to 50.

Abstract

Objective
The goal of this course is to provide the students with an understanding and the tools to develop their own mathematical models, to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

Content
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

Lecture notes
Copies of overheads will be made available.

Literature
There will be a required textbook that students need to purchase: Willi Gujer (2008): Systems Analysis for Water Technology. Springer-Verlag, Berlin Heidelberg

Prerequisites / notice
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel with the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

Taught competencies

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151-0573-00L System Modeling

Introduction to system modeling for control. Generic modeling approaches based on first principles, Lagrangian formalism, energy approaches and experimental data. Model parametrization and parameter estimation. Basic analysis of linear and nonlinear systems.

Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.

This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronic, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.

Lecture notes
The handouts in English will be available in digital form.

Literature
A list of references is included in the handouts.
### Taught competencies

<table>
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<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Domain C - Social Competencies</td>
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<td>Domain D - Personal Competencies</td>
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### 151-0575-01L - Signals and Systems

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<td>L. Carron</td>
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**Abstract**

Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**

Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercises.

**Content**


**Lecture notes**

Lecture notes available on course website.

**Prerequisites / notice**

Control Systems I is helpful but not required.

### 151-0591-00L - Control Systems I

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<td>L. Guzzella</td>
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**Abstract**

Analysis and controller synthesis for linear time invariant systems with one input and one output signal (SISO); transition matrix; stability; controllability; observability; Laplace transform; transfer functions; transient and steady state responses. PID control; dynamic compensators; Nyquist theorem.

**Objective**

Identify the role and importance of control systems in everyday life. Obtain models of single-input single-output (SISO) linear time invariant (LTI) dynamical systems. Linearization of nonlinear models. Interpret stability, observability and controllability of linear systems. Describe and associate building blocks of linear systems in time and frequency domain with equations and graphical representations (Bode plot, Nyquist plot, root locus). Design feedback controllers to meet stability and performance requirements for SISO LTI systems. Explain differences between expected and actual control results. Notions of robustness and other nuisances such as discrete time implementation.

**Content**


**Lecture notes**


In addition, the slides of the lecture will be put online.

**Literature**


**Prerequisites / notice**

Basic knowledge of (complex) analysis and linear algebra.

### 151-0601-00L - Theory of Robotics and Mechatronics

<table>
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<tr>
<th>W 4 credits</th>
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<td>P. Korba, S. Stoeter</td>
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**Abstract**

We further explore how we can discover basic system properties by exciting a system with various types of signals. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**

Identify the role and importance of control systems in everyday life. Obtain models of single-input single-output (SISO) linear time invariant (LTI) dynamical systems. Linearization of nonlinear models. Interpret stability, observability and controllability of linear systems. Describe and associate building blocks of linear systems in time and frequency domain with equations and graphical representations (Bode plot, Nyquist plot, root locus). Design feedback controllers to meet stability and performance requirements for SISO LTI systems. Explain differences between expected and actual control results. Notions of robustness and other nuisances such as discrete time implementation.

**Content**


**Lecture notes**


In addition, the slides of the lecture will be put online.

**Literature**


**Prerequisites / notice**

Basic knowledge of (complex) analysis and linear algebra.
Abstract
This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Objective
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Content
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Lecture notes
Available

151-0709-00L
Stochastic Methods for Engineers and Natural Scientists

Abstract
The course provides an introduction into stochastic methods that are applicable for example for the description and modeling of turbulent and subsurface flows. Moreover, mathematical techniques are presented that are used to quantify uncertainty in various engineering applications.

Objective
By the end of the course you should be able to mathematically describe random quantities and their effect on physical systems. Moreover, you should be able to develop basic stochastic models of such systems.

Content
- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation
All topics are illustrated with engineering applications.

Lecture notes
Detailed lecture notes will be provided.

Literature
Some textbooks related to the material covered in the course:

227-0076-00L
Electrical Engineering II

Abstract
Sinusoidal signals and systems in the time and frequency domain, principle of operation and design of basic analog and digital circuits as well as analog-digital conversion. Basic power electronic circuits, design of magnetic components, electromechanical energy conversion, principle of operation and characteristics of transistors and selected rotating electrical machines.

Objective
see above

Content

227-0116-00L
VLSI 1: HDL based design for FPGAs

Abstract
This first course in a series that extends over three consecutive terms is concerned with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.
Prerequisites / notice
Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

| Lecture notes | Textbook and all further documents in English. |
| Prerequisites | Basics of digital circuits. |

Prerequisites:
Basics of digital circuits.
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural

Analytical Competencies

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Not assessed

Taught

Competencies

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Physical Modelling and Simulation

W

6 credits

4G

J. Smajic

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in small projects.

Domain D - Personal Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Communication

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

227-2037-00L

Discovering Management

W

3 credits

3G


Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercises) 351-0778-01.

Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

These course materials will form the point of departure for the lectures, class discussions and team work.

Domain A - Subject-specific Competencies

Concepts and Theories

Analytical Competencies

Communication

Creative Thinking

Domain B - Method-specific Competencies

Techniques and Technologies

Problem-solving

Self-presentation and Social Influence

Critical Thinking

Domain C - Social Competencies

Customer Orientation

Leadership and Responsibility

Sensitivity to Diversity

Domain D - Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

351-0778-01L

Discovering Management (Exercises)

W

1 credit

1U

B. Clarysse, L. P. T. Vandeweghe

Complementary exercises for the module Discovering Management.

Autumn Semester 2021

Page 1140 of 2152
The course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

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All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

The students should submit the necessary information and the consequence of small changes are discussed.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts.

These are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

The students should submit the necessary information.
until September 13 and apply to anilsethi@ethz.ch

Abstract
This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective
Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs
2. The students can be from business or science & technology
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.

Content
The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay
8. Legal overview, company forms and shareholders' agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes
Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

Prerequisites / notice
This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

Taught competencies

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th>Media and Digital Technologies</th>
<th>Project Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain C - Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>Customer Orientation</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td></td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>Self-direction and Self-management</td>
</tr>
</tbody>
</table>

363-1109-00L Introduction to Microeconomics

W 3 credits 2G M. Wörter, M. Beck

GESS (Science in Perspective):
This course is only for students enrolled in a Bachelor's degree programme.

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

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

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

Objective
Students acquire a deeper understanding of basic microeconomic models.

They acquire the ability to apply these models in the interpretation of real world economic contexts.

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

Content
Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

Lecture notes
Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Literature
Prerequisites / notice Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Abstract
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.

Objective
The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content
- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature
- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

376-1177-00L Human Factors I
W 3 credits 2V
M. Menozzi Jäckli, R. Huang, M. Siegrist

401-0353-00L Analysis 3
W 4 credits 2V+2U
M. Iacobelli

Abstract
In this lecture we treat problems in applied analysis. The focus lies on the solution of quasilinear first order PDEs with the method of characteristics, and on the study of three fundamental types of partial differential equations of second order: the Laplace equation, the heat equation, and the wave equation.

Objective
The aim of this class is to provide students with a general overview of first and second order PDEs, and teach them how to solve some of these equations using characteristics and/or separation of variables.

Content
1.) General introduction to PDEs and their classification (linear, quasilinear, semilinear, nonlinear / elliptic, parabolic, hyperbolic)

2.) Quasilinear first order PDEs
- Solution with the method of characteristics
- Conservation laws

3.) Hyperbolic PDEs
- Wave equation
- d'Alembert formula in (1+1)-dimensions
- Method of separation of variables

4.) Parabolic PDEs
- Heat equation
- Maximum principle
- Method of separation of variables

5.) Elliptic PDEs
- Laplace equation
- Maximum principle
- Method of separation of variables
- Variational method

Literature

Prerequisites / notice
Prerequisites: Analysis I and II, Fourier series (Complex Analysis)

401-0625-01L Applied Analysis of Variance and Experimental Design
W 5 credits 2V+1U
L. Meier

Abstract
Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorial and fractional designs, power.

Objective
Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Author/Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-4623-00L</td>
<td>Time Series Analysis</td>
<td>6</td>
<td>W</td>
<td>F. Balabdaoui</td>
</tr>
<tr>
<td>401-7855-00L</td>
<td>Computational Astrophysics (University of Zurich)</td>
<td>6</td>
<td>W</td>
<td>L. M. Mayer</td>
</tr>
<tr>
<td>402-0809-00L</td>
<td>Introduction to Computational Physics</td>
<td>8</td>
<td>W</td>
<td>A. Adelmann</td>
</tr>
<tr>
<td>402-1701-00L</td>
<td>Physics I</td>
<td>7</td>
<td>W</td>
<td>K. Ensslin</td>
</tr>
<tr>
<td>636-0007-00L</td>
<td>Computational Systems Biology</td>
<td>6</td>
<td>W</td>
<td>J. Stelling</td>
</tr>
</tbody>
</table>

**Course Descriptions**

- **Time Series Analysis**: The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.
- **Computational Astrophysics (University of Zurich)**: The key topics which will be covered as:
  - Stationarity
  - Autocorrelation
  - Trend estimation
  - Elimination of seasonality
  - Spectral analysis, spectral densities
  - Forecasting
  - ARMA, ARIMA, Introduction into GARCH models
- **Introduction to Computational Physics**: This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.
- **Physics I**: This course gives a first introduction to Physics with an emphasis on classical mechanics. Skills in solving physics problems.
- **Computational Systems Biology**: Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).
The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students

A provisional week-by-week schedule (subject to change) is as follows:

<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.</td>
</tr>
<tr>
<td>3</td>
<td>Week 3: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.</td>
</tr>
<tr>
<td>4</td>
<td>Week 4: Staggered grid for formulating momentum and continuity equations. Indexing of unknowns. Solving momentum and continuity equations in case of constant viscosity using pressure-velocity formulation with staggered grid.</td>
</tr>
<tr>
<td>5</td>
<td>Weeks 5: Conservative finite differences for the momentum equation. “Free slip” and “no slip” boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.</td>
</tr>
<tr>
<td>7</td>
<td>Week 7: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.</td>
</tr>
<tr>
<td>9</td>
<td>Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.</td>
</tr>
<tr>
<td>10</td>
<td>Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.</td>
</tr>
<tr>
<td>11</td>
<td>Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.</td>
</tr>
<tr>
<td>12</td>
<td>Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.</td>
</tr>
</tbody>
</table>

GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

## Literature
ETH Week 2021: Health for Tomorrow

All ETH Bachelor’s, Master’s and exchange students can take part in the ETH week. No prior knowledge is required.

Abstract

ETH Week is an innovative one-week course designed to foster critical thinking and creative learning. Students from all departments as well as professors and external experts will work together in interdisciplinary teams. They will develop interventions that could play a role in solving some of our most pressing global challenges. In 2021, ETH Week will focus on the topic of health and well-being.

Objective

- Domain specific knowledge: Students have immersed knowledge about a certain complex, societal topic which will be selected every year. They understand the complex system context of the current topic, by comprehending its scientific, technical, political, social, ecological and economic perspectives.

- Analytical skills: The ETH Week participants are able to structure complex problems systematically using selected methods. They are able to acquire further knowledge and to critically analyse the knowledge in interdisciplinary groups and with experts and the help of team tutors.

- Design skills: The students are able to use their knowledge and skills to develop concrete approaches for problem solving and decision making to a selected problem statement, critically reflect these approaches, assess their feasibility, to transfer them into a concrete form (physical model, prototypes, strategy paper, etc.) and to present this work in a creative way (role-plays, videos, exhibitions, etc.).

- Self-competence: The students are able to plan their work effectively, efficiently and autonomously. By considering approaches from different disciplines they are able to make a judgment and form a personal opinion. In exchange with non-academic partners from business, politics, administration, nongovernmental organisations and media they are able to communicate appropriately, present their results professionally and creatively and convince a critical audience.

- Social competence: The students are able to work in multidisciplinary teams, i.e. they can reflect critically their own discipline, debate with students from other disciplines and experts in a critical-constructive and respectful way and can relate their own positions to different intellectual approaches. They can assess how far they are able to actively make a contribution to society by using their personal and professional talents and skills and as “Change Agents”.

- Remote collaboration competence: The students work in a hybrid setting blending physical and virtual communication and collaboration methods and tools. They experience the potential and limitations of remote collaboration.

Content

The week is mainly about problem solving and design thinking applied to the complex world of health and well-being. During ETH Week students will have the opportunity to work in small interdisciplinary groups, allowing them to critically analyse both their own approaches and those of other disciplines, and to integrate these into their work.

While deepening their knowledge about health and well-being, students will be introduced to various methods and tools for generating creative ideas and understand how different people are affected by each part of the system. In addition to lectures and literature, students will acquire knowledge via excursions into the real world, empirical observations, and conversations with researchers and experts.

A key attribute of the ETH Week is that students are expected to find their own problem, rather than just solve the problem that has been handed to them.

Therefore, the first three days of the week will concentrate on identifying a problem the individual teams will work on, while the last two days are focused on generating solutions and communicating the team’s ideas.

Prerequisites / notice

No prerequisites. Programme is open to Bachelor and Masters from all ETH Departments. All students must apply through a competitive application process at www.ethz.ch/ethweek. Participation is subject to successful selection through this competitive process.

Taught competencies

Domain B - Method-specific Competencies
- Analytical Competencies
- Media and Digital Technologies
- Problem-solving
- Communication
- Negotiation
- Sensitivity to Diversity
- Cooperation and Teamwork

Domain C - Social Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Self-direction and Self-management

Domain D - Personal Competencies
- Reflect on their approach to teaching as well as their attitude towards teaching.
- Understand the basics of teaching and learning in the context of their subject.
- Consciously design the introduction of their course as well as the introduction of single learning units.
- Apply classroom assessment techniques as formative assessments to measure the current status of their students.
- Develop a didactic concept according to the learning objectives.
- Conduct interactive sequences as learning activities.
- Give and get feedback from peers and self-reflect on their teaching practice.

The online course provide a range of relevant topics for developing teaching competences of Student Teaching Assistants: Overview about how learning works. Based on these fundamentals of learning participants reflect on their role as Student TAs to feel comfortable in their new role as a teacher.

Prerequisites / notice

Self-paced online course: https://moodle-app2.let.ethz.ch/course/view.php?id=15127

Consolidation Workshops in November (dates will be announced in the online course at the beginning of the semester)
Science in Perspective

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-INFK.

Language Courses

see Science in Perspective: Language Courses ETH/UZH

Bachelor's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0500-00L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
The Bachelor thesis is the final requirement of the BSc program and is supervised by one of the D-INFK professors. The thesis encourages students to show and produce a scientifically structured work.

Objective
In their BSc thesis students should demonstrate their ability to carry out independent, structured scientific work.

Prerequisites / notice
The supervisor of the thesis defines the task, start and end date.

A written report will be prepared on the scientific studies carried out, followed by a final presentation.

The thesis must be handed in within 6 months.

Computer Science Bachelor - Key for Type

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

Key for Hours

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

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Educational Science

General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in</td>
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<tr>
<td></td>
<td>the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;.</td>
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<td></td>
<td>It is about learning in childhood and adolescence.</td>
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<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical</td>
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<tr>
<td></td>
<td>studies on human learning and relates them to the school.</td>
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<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all</td>
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<td></td>
<td>understand the learning process. Against this background,</td>
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<td></td>
<td>theories and findings on the way human processes inform</td>
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<td></td>
<td>and human behaviour are prepared in such a manner that they</td>
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<tr>
<td></td>
<td>can be used for planning and conducting lessons. Students</td>
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<td></td>
<td>additionally gain an understanding of what is going on in</td>
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<td></td>
<td>and behavioural research so that teachers are put in a</td>
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<td></td>
<td>position where they can further educate themselves in the</td>
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<tr>
<td></td>
<td>field of research into teaching and learning.</td>
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<tr>
<td>Content</td>
<td>Thematische Schwerpunkte:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lernen als Verhaltensänderung und als Informationsverarbeitung:</td>
<td></td>
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<tr>
<td></td>
<td>Das menschliche Gedächtnis unter besonderer Berücksichtigung</td>
<td></td>
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<tr>
<td></td>
<td>der Verarbeitung symbolischer Information; Lernen als</td>
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<tr>
<td></td>
<td>Wissenskonstruktion und Kompetenzwerbung unter besonderer</td>
<td></td>
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<tr>
<td></td>
<td>Berücksichtigung des Wissensstransfers; Lernen durch</td>
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<tr>
<td></td>
<td>Instruktion und Erklärungen: Die Rolle von Emotion und</td>
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<tr>
<td></td>
<td>Motivation beim Lernen; Interindividuelle</td>
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<tr>
<td></td>
<td>Unterschiede in der Lernfähigkeit und ihre Ursachen:</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Folien werden zur Verfügung gestellt.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites/</td>
<td>This lecture is only apt for students who intend to enrol in</td>
<td></td>
<td></td>
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<tr>
<td>notice</td>
<td>the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;.</td>
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<tr>
<td></td>
<td>It is about learning in childhood and adolescence.</td>
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<tr>
<td>851-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W D2)</td>
<td>2</td>
<td>3</td>
<td>2S</td>
<td>U. Markwalder, S. Maurer, S. Peteranderl-Rüschoff</td>
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<tr>
<td></td>
<td>Number of participants limited to 20.</td>
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<tr>
<td>Abstract</td>
<td>The successful participation in EW1 (&quot;Human Learning&quot;)</td>
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<tr>
<td></td>
<td>and EW2 (&quot;Designing Learning Environments for School&quot;)</td>
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<td></td>
<td>is recommended, but not a mandatory prerequisite.</td>
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<tr>
<td>Objective</td>
<td>In this class, students will learn concepts and skills for</td>
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<td></td>
<td>coping with psychosocial demands of teaching</td>
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<td></td>
<td>(1) They know relevant rules of conversation and conflict</td>
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<td>management and are able to apply them in an appropriate way</td>
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<td>in the school context (e.g. in parental talks).</td>
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<td>(2) They know core aspects of classroom management and know</td>
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<td>how to apply it concretely (e.g. promoting a positive</td>
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<td>learning atmosphere, avoiding disciplinary difficulties) and</td>
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<td>they are aware of possible contacts (e.g. illegal or</td>
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<td></td>
<td>psychological services).</td>
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<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects ■ W</td>
<td>2</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
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<td></td>
<td>Enrolment only possible with matriculation in Teaching</td>
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<td></td>
<td>Diploma or Teaching Certificate (excluding Teaching Diploma</td>
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<td></td>
<td>Sport).</td>
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<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful</td>
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<td></td>
<td>participation in, or during enrollment in the course &quot;Human</td>
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<td></td>
<td>Learning (EW 1)&quot;.</td>
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<tr>
<td>Objective</td>
<td>This seminar focuses on teaching units in chemistry, physics</td>
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<td></td>
<td>and mathematics that have been developed at the MINT</td>
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<td>Learning Center of the ETH Zurich. In the first meeting, the</td>
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<td></td>
<td>mission of the MINT Learning Center will be communicated.</td>
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<td></td>
<td>Furthermore, in groups of two, the students will intensively</td>
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<td></td>
<td>work on, refine and optimize a teaching unit following a</td>
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<td></td>
<td>goal set in advance.</td>
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<tr>
<td>Prerequisites /</td>
<td>Get to know cognitively activating instructions in MINT</td>
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<tr>
<td>notice</td>
<td>subjects.</td>
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<tr>
<td></td>
<td>Get information about recent literature on learning and</td>
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<td></td>
<td>instruction.</td>
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<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>1</td>
<td>1</td>
<td>2S</td>
<td>E. Stern</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching</td>
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<td>Diploma or Teaching Certificate (excluding Teaching Diploma</td>
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<td></td>
<td>Sport).</td>
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<tr>
<td>Abstract</td>
<td>Number of participants limited to 30.</td>
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<tr>
<td>Objective</td>
<td>The focus will be on the book &quot;Intelligenz: Grosse</td>
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<tr>
<td></td>
<td>Unterschiede und ihre Folgen&quot; by Stern and Neubauer.</td>
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<tr>
<td></td>
<td>Participation at the first meeting is obligatory. It is</td>
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<tr>
<td></td>
<td>required that all participants read the complete book.</td>
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<td></td>
<td>Furthermore, in two meetings of 90 minutes, concept papers</td>
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<td>developed in small groups (5 - 10 students) will be</td>
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<tr>
<td></td>
<td>discussed.</td>
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<tr>
<td>Prerequisites /</td>
<td>Understanding of research methods used in the</td>
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<tr>
<td>notice</td>
<td>empirical human sciences.</td>
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<td></td>
<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>1</td>
<td>2</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurm</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 30.</td>
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<tr>
<td>Abstract</td>
<td>This course unit can only be enrolled after successful</td>
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</tr>
<tr>
<td>Objective</td>
<td>participation in, or during enrollment in the course &quot;Human</td>
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<tr>
<td></td>
<td>Learning (EW 1)&quot;.</td>
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</tbody>
</table>
The course "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The course deals with the thoughtful choice of educational contents for computer science classes, which takes into account its comprehensibility for different age groups as well as didactic approaches suitable for a successful knowledge transfer.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The course "Subject Didactics of Computer Science I" addresses key contributions of computer science to general education. The chosen topics support the young learners in developing a unique and indispensable way of thinking, in enhancing their understanding of our world as well as in achieving university education entrance qualifications.

The main topics of the course unit "Subject Didactics of Computer Science I" are the didactics of finite state automata, of formal languages and of the introduction to programming. The unit focuses on contents of computer science that contribute to general education. This involves the understanding of fundamental scientific concepts such as algorithm, complexity, determinism, computation, automata, verification, testing and programming language as well as the way to embed them into a scientifically sound and didactically sustainable computer science course.

In a seminar exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

Lecture notes

Unterlagen und Folien werden zur Verfügung gestellt.
Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.


Prerequisites / notice

Lehrdipлом-Studierende müssen diese Lerneinheit zusammen mit dem Einführungspraktikum Informatik - 272-0201-00L - belegen.

Literature

271-0102-00L Teaching Internship Including Examination Lessons in Computer Science 4 credits 9P J. Hromkovic, G. Serafini

Teaching Internship Computer Science for TC.

Repetition of the Teaching Internship is excluded even if Examination Lessons are to be repeated.

Abstract

Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

Objective

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content


Lecture notes

Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Literature

Wird von der Praktikumslehrperson bestimmt.

272-0103-00L Mentored Work Subject Didactics Computer Science O 2 credits 4A J. Hromkovic, G. Serafini

Mentored Work Subject Didactics in Computer Science for TC and Teaching Diploma.

Abstract

In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/ or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective

- The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.
**Specialized Courses in Respective Subject with Educational Focus**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0400-00L</td>
<td>Mentored Work Specialised Courses in the Respective W+ Subject with Educational Focus Computer Sc A</td>
<td>W</td>
<td>2</td>
<td>4A</td>
<td>J. Hromovic, G. Serafini</td>
</tr>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
<tr>
<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>A. Steger</td>
</tr>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

**Abstract**

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

**Objective**

- To understand language concepts on a semantic level and be able to compare and evaluate language designs.
- To be able to learn new languages more rapidly.
- To be aware of many subtle problems of object-oriented programming and know how to avoid them.
- To convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

**Literature**


**Prerequisites / notice**

- The topics discussed in the course include among others:
  - The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
  - The key points and features of object-oriented programming languages and their support in different programming languages.
  - The situations in which object-oriented programming does not provide encapsulation and how to avoid them.
  - How to maintain the consistency of data structures

**Prerequisites:**

- Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

- Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

**Lecture notes / Literature**

- Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks

- Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

- Advanced Machine Learning provides analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.
Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes

No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

<table>
<thead>
<tr>
<th>Module</th>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-1407-00L</td>
<td>Algorithmic Game Theory</td>
<td>W</td>
<td>7 credits</td>
<td>3V+2U+1A</td>
<td>P. Penna</td>
</tr>
<tr>
<td>Objective</td>
<td>Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don't care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>No lecture notes, but slides will be made available on the course webpage.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least &quot;Introduction to Machine Learning&quot; or an equivalent course offered by another institution.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Module</th>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-2800-00L</td>
<td>Design of Parallel and High-Performance Computing</td>
<td>W</td>
<td>9 credits</td>
<td>3V+2U+3A</td>
<td>T. Hoeftler, M. Püschel</td>
</tr>
<tr>
<td>Objective</td>
<td>Advanced topics in parallel and high-performance computing. Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Number of participants limited to 125.</td>
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<td></td>
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</tr>
</tbody>
</table>
Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

Computer Science TC - Key for Type

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

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
</tbody>
</table>

**Abstract**
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)"

**Objective**
- Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction

**Prerequisites / notice**
Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
</tbody>
</table>

**Abstract**
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

**Objective**
- Understanding research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1 credit</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
</tr>
</tbody>
</table>

**Abstract**
Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

**Objective**
- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-11L</td>
<td>Gender Issues in Education and STEM</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
</tr>
</tbody>
</table>

**Abstract**
In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.

**Objective**
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.

**Content**
Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

**Prerequisites / notice**
Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

see Educational Science Teaching Diploma

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0238-01L</td>
<td>Support and Diagnosis of Knowledge Acquisition Processes (EW3)</td>
<td>W</td>
<td>3 credits</td>
<td>3S</td>
<td>P. Edelsbrunner, J. Maue, C. M. Thurn</td>
</tr>
</tbody>
</table>

**Abstract**
Enrolment only possible with matriculation in Teaching Diploma (except for students of Sport Teaching Diploma, who complete the sport-specific course unit EW3) and for students who intend to enrol in the "Teaching Diploma".

**Prerequisite**
Successful participation in course 851-0240-00L Human Learning (EW1).
Prerequisites: successful participation in 851-0240-00L "Human Learning (EW1)".

Abstract
In this seminar students learn advanced techniques to support and to diagnose knowledge acquisition processes in school.

Objective
The main goals are:
(1) You have a deep understanding about the cognitive mechanisms of knowledge acquisition.
(2) You have a basic understanding about psychological test theory and can appropriately administer tests.
(3) You know various techniques of formative assessment and can apply these to uncover students’ misconceptions.

Subject Didactics in Computer Science
Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0101-00L</td>
<td>Subject Didactics of Computer Science I</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>G. Serafini, J. Hromkovic</td>
</tr>
</tbody>
</table>

Abstract
The unit “Subject Didactics of Computer Science I” addresses key contributions of computer science to general education. The course deals with the thoughtful choice of educational contents for computer science classes, which takes into account its comprehensibility for different age groups as well as didactic approaches suitable for a successful knowledge transfer.

Objective
The general objective of the course consists in highlighting the tight connection between the mathematical and algorithmic way of thinking and the approaches adopted by engineering disciplines, and in reflecting on teaching approaches for sustainable computer science teaching activities.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

Content
The course “Subject Didactics of Computer Science I” addresses key contributions of computer science to general education. The chosen topics support the young learners in developing a unique and indispensable way of thinking, in enhancing their understanding of our world as well as in achieving university education entrance qualifications.

The main topics of the course unit “Subject Didactics of Computer Science I” are the didactics of finite state automata, of formal languages and of the introduction to programming. The unit focuses on contents of computer science that contribute to general education. This involves the understanding of fundamental scientific concepts such as algorithm, complexity, determinism, computation, automata, verification, testing and programming language as well as the way to embed them into a scientifically sound and didactically sustainable computer science course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

Lecture notes
Unterlagen und Folien werden zur Verfügung gestellt.

Literature


Prerequisites / notice
Lehrdiplom-Studierende müssen diese Lerneinheit zusammen mit dem Einführungspraktikum Informatik - 272-0201-00L - belegen.
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Thematic Schwerpunkte

Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

- Lernformen

- Literature
  Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

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

## Professional Training

### Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>272-0201-00L</td>
<td>Introductory Practical in Computer Science</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>J. Hromkovic, G. Serafini</td>
</tr>
</tbody>
</table>

**Abstract**

During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

**Domain A - Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**

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

**Domain C - Social Competencies**

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

**Domain D - Personal Competencies**

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

**Teaching Diploma and for students upgrading TC to**

**Mentored Work Subject Didactics in Computer Science for**

- A
  Mentored Work Subject Didactics in Computer Science for TC and Teaching Diploma.
  
  **Abstract**
  In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

  **Objective**
  The objective is for the students:
  - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
  - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

  **Content**
  Thematic Schwerpunkte
  Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

  - Lernformen

  - Literature
    Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

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

**Teaching Diploma and for students upgrading TC to**

**Mentored Work Subject Didactics in Computer Science for**

- B
  Mentored Work Subject Didactics in Computer Science for Teaching Diploma and for students upgrading TC to Teaching Diploma.
  
  **Abstract**
  In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

  **Objective**
  The objective is for the students:
  - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
  - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

  **Content**
  Thematic Schwerpunkte
  Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

  - Lernformen

  - Literature
    Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird sie vom Betreuer zur Verfügung gestellt.

  - Prerequisites / notice
    Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.
Objective
Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to, and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

Content
The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content
The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0202-00L

Professional Exercises

In the course Professional Exercises the students achieve additional school-relevant experiences.

Objective
Achievement of additional school-relevant experiences. The students carry out individually specified, practice related projects, in which they support, document or reflect on learning processes.

Content
The course Professional Exercises offers the opportunity for additional school-relevant activities.

Objective
- The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0203-00L

Teaching Internship in Computer Science

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter and didactic skills they have acquired in the course of their training.

Objective
- They learn to assess pupils' work.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content
The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0204-00L

Teaching Internship in Computer Science

In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter and didactic skills they have acquired in the course of their training.

Objective
- They learn to assess pupils' work.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content
The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0205-01L

Examination Lesson I in Computer Science

Simultaneous enrolment in "Examination Lesson II in Computer Science" (272-0205-02L) is compulsory.

Objective
- In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Content
The students are supported by the lecturers or by experienced teachers. They assist teachers at school, they create training systems and tests, correct the written homework of pupils and evaluate the progress of a class. The students create explanations and detailed solutions to exercises with respect to the actual knowledge of the pupils. A written assignment states the exact scope of the activity.

272-0205-02L

Examination Lesson II in Computer Science

Simultaneous enrolment in "Examination Lesson I in Computer Science" (272-0205-01L) is compulsory.

Objective
- In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.
Themenatische Schwerpunkte:
On the basis of a specified topic, the candidate shows that they are in a position

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Type

Thematische Schwerpunkte:
Mentored Work Specialised Courses in the Respective

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

The aim is for the students

Lecturers
J. Hromkovic, G. Serafini

Mentored Work Specialised Courses in the Respective
Objectives
After this course, students will:

- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle

4A

Subject with Educational Focus Computer Sc A

Content
Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten sie Informationen über den Wissensstand der zu unterrichtenden Klasse und können sie vor dem Prüfungstermin besuchen. Sie erstellen eine Vorbereitungsmappe anleitung und reichen sie bis am Vortag um 12 Uhr den beiden Prüfungsexperten ein.

Die gehaltene Lektion wird kritiernbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Refexion des Kandidaten/ der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice

Nach Abschluss der übrigen Ausbildung.


Number
272-0400-00L

Title
Mentored Work Specialised Courses in the Respective O
Subject with Educational Focus Computer Sc A

Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objectives
- to individually develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Lecturers
J. Hromkovic, G. Serafini

2 credits

4A

272-0401-00L

Mentored Work Specialised Courses in the Respective O
Subject with Educational Focus Computer Sc B

Abstract
In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objectives
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Lecturers
J. Hromkovic, G. Serafini

2 credits

4A

252-0237-00L

Concepts of Object-Oriented Programming

Abstract
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

Objective
After this course, students will:

- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

Content
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:

- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)

- The key problems of single and multiple inheritance and how different languages address them

- Generic type systems, in particular, Java generics, C# generics, and C++ templates

- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them

- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing

- How to maintain the consistency of data structures

Literature
Will be announced in the lecture.

Prerequisites / notice
Prerequisites:
Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>W</th>
<th>Credits</th>
<th>V</th>
<th>U</th>
<th>A</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td></td>
<td>10</td>
<td>3V+2U+4A</td>
<td>A. Steger</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract
Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks

Objective
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.

Content
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Lecture notes
Yes.

Literature

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory
- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks
- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-1407-00L Algorithmic Game Theory W 7 credits 3V+2U+1A P. Penna

Abstract
Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.

Objective
Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.
The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don't care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

Outline:
- Introduction to classic game-theoretic concepts.
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity.
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization.
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the 'Price of Anarchy').
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium.
- Selected current research topics, such as Google's Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

Lecture notes will be usually posted on the website shortly after each lecture.

Literature
"Game Theory and Strategy", Philip D. Straffin, The Mathematical Association of America, 5th printing, 2004

Several copies of both books are available in the Computer Science library.

Audience: Although this is a Computer Science course, we encourage the participation from all students who are interested in this topic.

Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

263-2800-00L Design of Parallel and High-Performance Computing W 9 credits 3V+2U+3A T. Hoefler, M. Püschel

Number of participants limited to 125.

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)* and "Algorithmen und Datenstrukturen (algorithm and data structures)* or equivalent courses.

Compulsory Elective Courses
Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

see Compulsory Elective Courses Teaching Diploma

Computer Science Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### 263-3010-00L Big Data

#### Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations. This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage (S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRML, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

#### Objective

This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

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- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRML, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
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- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

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- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

The first part of the lecture covers individual system's aspects starting with tamperproof or tamper-resistant hardware in general over common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

The second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Objective
The course will cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Content

Literature
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

Prerequisites
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
</tr>
<tr>
<td>Abstract</td>
<td>Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.</td>
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<tr>
<td>Objective</td>
<td>Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solving modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.</td>
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</tr>
<tr>
<td>Content</td>
<td>The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both per-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.</td>
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</table>

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation

Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

<table>
<thead>
<tr>
<th>Number</th>
<th>System Security</th>
<th>W</th>
<th>7</th>
<th>2V+2U+2A</th>
<th>S. Capkun, A. Perrig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.</td>
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</tr>
<tr>
<td>Objective</td>
<td>In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.</td>
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</tr>
<tr>
<td>Content</td>
<td>The first part of the lecture covers individual system's aspects starting with tamperproof or tamperresistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.</td>
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</table>

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations. Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology. The participation in the course is subject to the following condition:

- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The goal is not to provide a comprehensive introduction to formal methods - this is well covered by other courses in the department. Instead, it is intended to provide students in computer systems (who may or may not have existing background knowledge of formal methods) with a basis for applying formal methods in their work.

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Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
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Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The goal is not to provide a comprehensive introduction to formal methods - this is well covered by other courses in the department. Instead, it is intended to provide students in computer systems (who may or may not have existing background knowledge of formal methods) with a basis for applying formal methods in their work.

This course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written both by students taking the course, and practical systems developed using formal techniques, in particular the verified sat4j microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

No lecture notes, but slides will be made available on the course webpage.


This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

**Abstract**
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

**Objective**
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

**Prerequisites / notice**
This course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

- Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
- Defenses against attacks
- Combining gradient-based optimization with logic for encoding background knowledge
- Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
- Probabilistic certification of deep neural networks
- Training deep neural networks to be provably robust via automated reasoning
- Fairness (different notions of fairness, certifiably fair representation learning)
- Federated Learning (intro, security considerations)

For solving assignments, some programming experience in Python is expected.
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
- Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Major in Secure and Reliable Systems

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0237-00L</td>
<td>Concepts of Object-Oriented Programming</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>P. Müller</td>
</tr>
</tbody>
</table>

Abstract
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

Objective
After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them
- Generic type systems, in particular, Java generics, C# generics, and C++ templates
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
- How to maintain the consistency of data structures

Literature
Will be announced in the lecture.

Prerequisites / notice
Prerequisites:
Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

252-0463-00L Security Engineering W 7 credits 2V+2U+2A S. Krstic

Abstract
Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems

Objective
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
Content

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature

- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice

Prerequisite: Class on Information Security

252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, A. Perrig

Abstract

The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers individual system’s aspects starting with tamperproof or tamperresistant hardware in general over tamper-proofing of the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

263-2800-00L Design of Parallel and High-Performance Computing W 9 credits 3V+2U+3A T. Hoeffler, M. Püschel
Number of participants limited to 125.
Abstract
Advanced topics in parallel and high-performance computing.
Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.
Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.
Prerequisites / notice
This class is intended for Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)” and “Algorithmen und Datenstrukturen (algorithm and data structures)” or equivalent courses.

263-4640-00L Network Security W 8 credits 2V+2U+3A A. Perrig, S. Frei, M. Legner, K. Paterson
Abstract
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.
Objective
This course provides an in-depth study of network attack techniques and methods to defend against them. Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.
Content
The course will cover topics spanning four broad themes with a focus on the first two themes:
1) Network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2) Network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3) Analysis and inference topics such as traffic monitoring and network forensics; and
4) New technologies related to next-generation networks.
Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-1411-00L</td>
<td>Security of Wireless Networks</td>
<td>W</td>
<td>6</td>
<td>2V+1U+2A</td>
<td>S. Capkun, K. Kostiainen</td>
</tr>
</tbody>
</table>

Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.
Objective
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

Content

263-2400-00L Reliable and Trustworthy Artificial Intelligence

Abstract
Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting advances that bring us closer to constructing such models.

Objective
The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.

To facilitate deeper understanding, an important part of the course will be a group hands-on programming project where students will build a system based on the learned material.

Content
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

* Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
* Defenses against attacks
* Combining gradient-based optimization with logic for encoding background knowledge
* Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
* Probabilistic certification of deep neural networks
* Training deep neural networks to be provably robust via automated reasoning
* Fairness (different notions of fairness, certifiably fair representation learning)
* Federated Learning (introduction, security considerations)

Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

For solving assignments, some programming experience in Python is expected.

263-4657-00L Advanced Encryption Schemes

Abstract
Public-Key Encryption has had a significant impact by enabling remote parties to communicate securely via an insecure channel. Latest schemes go further by providing a fine-grained access to the encrypted data.

Objective
The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

Content
We will start by presenting the notion of Public-Key Encryption with its various security guarantees and some constructions. Then we will look into encryption schemes with fine-grained access control to the encrypted data, such as identity-based encryption or attribute-based encryption and present different methodology to prove their security.

Literature
Links to relevant research papers will be given in the course materials.

Prerequisites / notice
It is recommended for students to have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Advanced Cryptography".

263-4655-00L Zero-Knowledge Proofs

Abstract
This course is a detailed introduction to zero-knowledge proof protocols.

Objective
To understand various methods of constructing zero-knowledge proof protocols, and be able to analyse their security properties.

Content
The course will discuss interactive zero-knowledge proofs based on various commitment schemes, and explore connections to other areas like secure multi-party computation. The course may also describe some more advanced constructions of non-interactive proofs.

Prerequisites / notice
Students should have taken a first course in Cryptography (as taught in the Information Security course at Bachelor's level). Confidence with algebra and probability is desirable.

227-0579-00L Hardware Security

Abstract
This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures, reviewing and discussing papers, and executing some of these advanced attacks.

Objective
By the end of the course, the students will be familiar with the state of the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Literature
Slides, relevant literature and manuals will be made available during the course.

Prerequisites / notice
Knowledge of systems programming and computer architecture is a plus.

Major in Theoretical Computer Science

Core Courses

Number | Title | Type | ECTS | Hours | Lecturers
---|---|---|---|---|---
252-0417-00L | Randomized Algorithms and Probabilistic Methods | W | 10 credits | 3V+2U+4A | A. Steger

Abstract
Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshhev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks

Objective
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals: What is data?
- Bayesian Learning
- Computational learning theory
- Supervised learning: Ensembles: Bagging and Boosting Max Margin methods
- Neural networks
- Unsupervised learning: Dimensionality reduction techniques Clustering Mixture Models Non-parametric density estimation Learning Dynamical Systems

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

Advanced Machine Learning

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals: What is data?
- Bayesian Learning
- Computational learning theory
- Supervised learning: Ensembles: Bagging and Boosting Max Margin methods
- Neural networks
- Unsupervised learning: Dimensionality reduction techniques Clustering Mixture Models Non-parametric density estimation Learning Dynamical Systems

Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

Advanced Algorithms

Abstract

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

Objective

This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

Content

This course covers advanced topics in algorithm design, including approximation algorithms, online algorithms, sketching, streaming, and online algorithms. Students will learn how to design and analyze algorithms for a wide range of computational problems.
### Content

The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

### Lecture notes

https://people.inf.ethz.ch/gmohsen/A221/

### Prerequisites / notice

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations, E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.

### Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-1407-00L</td>
<td>Algorithmic Game Theory</td>
<td>W</td>
<td>7</td>
<td>3V+2U+1A</td>
<td>P. Penna</td>
</tr>
</tbody>
</table>

**Abstract**

Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.

**Objective**

Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.

**Content**

The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don't care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

**Outline:**

- Introduction to classic game-theoretic concepts
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the 'Price of Anarchy')
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium
- Selected current research topics, such as Google's Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

**Lecture notes**

Lecture notes will be usually posted on the website shortly after each lecture.

**Literature**


"Game Theory and Strategy", Philip D. Straffin, The Mathematical Association of America, 5th printing, 2004

**Prerequisites / notice**

Audience: Although this is a Computer Science course, we encourage the participation from all students who are interested in this topic.

Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0417-00L</td>
<td>Information Theory I</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>A. Lapidoth</td>
</tr>
</tbody>
</table>

**Abstract**

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

**Objective**

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

**Content**

The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

**Literature**

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3055-64L</td>
<td>Algebraic Methods in Combinatorics</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>B. Sudakov</td>
</tr>
</tbody>
</table>

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods, Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem. Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

**Lecture notes**

Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

Major in Visual and Interactive Computing

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0543-01L</td>
<td>Computer Graphics</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Does not take place this semester.</em></td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td><strong>Content</strong></td>
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<td><strong>Lecture notes</strong></td>
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<td><strong>Literature</strong></td>
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<td><strong>Prerequisites / notice</strong></td>
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263-5902-00L | Computer Vision               | W    | 8    | 3V+1U+3A   | M. Pollefeys, S. Tang, F. Yu |
|            | *The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.*                   |      |      |             |               |
|            | **Abstract**                        |      |      |             |               |
|            | **Objective**                       |      |      |             |               |
|            | **Content**                         |      |      |             |               |
|            | **Prerequisites / notice**          |      |      |             |               |

### Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0546-00L</td>
<td>Physically-Based Simulation in Computer Graphics</td>
<td>W</td>
<td>5 credits</td>
<td>2+1+1</td>
<td>V. da Costa de Azevedo, B. Solenthaler, B. Thomaszewski</td>
</tr>
</tbody>
</table>

**Abstract**
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

**Objective**
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

**Content**
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

**Prerequisites / notice**
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>263-5905-00L</td>
<td>Mixed Reality</td>
<td>W</td>
<td>5 credits</td>
<td>3G+1A</td>
<td>I. Armeni, F. Bogo, M. Pollefeys</td>
</tr>
</tbody>
</table>

**Abstract**
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

**Objective**
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

**Content**
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

**Prerequisites / notice**
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

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### Seminar

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-3811-00L</td>
<td>Case Studies from Practice Seminar</td>
<td>W</td>
<td>4 credits</td>
<td>2S</td>
<td>M. Brandis</td>
</tr>
</tbody>
</table>

**Abstract**
Participants will learn how to analyze and solve IT problems in practice in a systematic way, present findings to decision bodies, and defend their conclusions.

**Objective**
Participants understand the different viewpoints for IT-decisions in practice, including technical and business aspects, can effectively analyze IT questions from the different viewpoints and facilitate decision making.

**Content**
Participants learn how to systematically approach an IT problem in practice. They work in groups of three to solve a case from a participating company in depth, studying provided materials, searching for additional information, analyzing all in depth, interviewing members from the company or discussing findings with them to obtain further insights, and presenting and defending their conclusion to company representatives, the lecturer, and all other participants of the seminar. Participants also learn how to challenge presentations from other teams, and obtain an overview of learnings from the cases other teams worked on.

**Lecture notes**
Methodologies to analyze the cases and create final presentations. Short overview of each case.

**Prerequisites / notice**
Successful completion of Lecture "Case Studies from Practice".
Each student will be asked to study some papers from the recent software engineering literature and review them. This is an exercise in critical review and analysis. Active participation is required (a presentation of a paper as well as participation in discussions).

The seminar will officially fail the seminar.

Number of participants limited to 24.

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

The seminar covers topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

The reading list will be published on the course web site.

The papers will be presented in the first session of the seminar.

The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

The seminar covers advanced topics in computer graphics, including modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each student presents one paper to the class and leads a discussion about the paper and related topics.

The seminar covers advanced topics in computer graphics, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each student presents one paper to the class and leads a discussion about the paper and related topics.

The seminar covers advanced topics in computer graphics and vision, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

The seminar covers advanced topics in computer vision, graphical models and machine learning.

The seminar familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

The publications to be presented will be announced on the seminar home page at least one week before the first presentation. Please consult the seminar's home page for information.

This seminar is an opportunity to become familiar with current research in software engineering and more generally with the methods and challenges of scientific research.

The aim of this seminar is to introduce students to recent research results in the area of programming languages and software engineering. To accomplish that, students will study and present research papers in the area as well as participate in paper discussions. The papers will span topics in both theory and practice, including papers on program verification, program analysis, testing, programming language design, and development tools. A particular focus will be on domain-specific languages.

The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.
Objective
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Content
The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, high performance computing, data appliances, and data centers.

Prerequisites / notice
Students taking this seminar should have the necessary background in systems and low level programming.

263-3713-00L Advanced Topics in Human-Centric Computer Vision
W 2 credits 2S O. Hilliges
Numbers of participants limited to 20.
The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
In this seminar we will discuss state-of-the-art literature on human-centric computer vision topics including but not limited to human pose estimation, hand and eye-gaze estimation as well as generative modelling of detailed human activities.

Objective
The learning objective is to analyze selected research papers published at top computer vision and machine learning venues. A key focus will be placed on identifying and discussing open problems and novel solutions in this space. The seminar will achieve this via several components: reading papers, technical presentations, writing analysis and critique summaries, class discussions, and exploration of potential research topics.

Content
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.
Reviewer: Perform a critical review of the paper.

Prerequisites / notice
Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Taught competencies
- Domain B - Method-specific Competencies: Analytical Competencies assessed
- Domain C - Social Competencies: Communication assessed
- Domain D - Personal Competencies: Critical Thinking assessed

263-4410-00L Seminar on Advanced Graph Algorithms and Optimization
W 2 credits 2S R. Kyng
Number of participants limited to 6!
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
This seminar aims to familiarize students with current research topics in fast graph algorithms and optimization.

Objective
Read papers on cutting edge research topics; learn how to give a scientific talk.

Content
We will study recent papers that made significant contributions in the areas in fast graph algorithms and optimization.

Prerequisites / notice
As prerequisite we require that you passed the course "Advanced Graph Algorithms and Optimization". In exceptional cases, students who passed one of the courses "Randomized Algorithms and Probabilistic Methods", "Optimization for Data Science", or "Advanced Algorithms" may also participate, at the discretion of the lecturer.

263-5156-00L Beyond iid Learning: Causality, Dynamics, and Interactions
W 2 credits 2S M. Mühlebach, A. Krause, B. Schölkopf
Number of participants limited to 60.
The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
Many machine learning problems go beyond supervised learning on independent data points and require an understanding of the underlying causal mechanisms, the interactions between the learning algorithms and their environment, and adaptation to temporal changes. The course highlights some of these challenges and relates them to state-of-the-art research.

Objective
Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Content
The goal of this seminar is to gain experience with machine learning research and foster interdisciplinary thinking.

Lecture notes
Further information will be published on the course website: https://beyond-iid-learning.xyz/

Prerequisites / notice
BSc in computer science or related field (engineering, physics, mathematics). Passed at least one learning course, such as "Introduction to Machine Learning" or "Probabilistic Artificial Intelligence".

Practical Work

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>252-0811-00L</td>
<td>Applied Security Laboratory</td>
<td>W</td>
<td>8</td>
<td>7P</td>
<td>C. Sprenger</td>
</tr>
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</table>

Abstract
Hands-on course on applied aspects of information security. Applied information security, operating system security, OS hardening, computer forensics, web application security, project work, design, implementation, and configuration of security mechanisms, risk analysis, system review.

Objective
The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, logging), application security with an emphasis on web applications (web server setup, common web exploits, authentication, session handling, code security), computer forensics, and risk analysis and risk management.
This course emphasizes applied aspects of Information Security. The students will study a number of topics in a hands-on fashion and carry out experiments in order to better understand the need for secure implementation and configuration of IT systems and to assess the effectivity and impact of security measures. This part is based on a book and virtual machines that include example applications, questions, and answers.

The students will also complete an independent project: based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

This course involves the participation in a substantial development and/or evaluation project involving distributed systems technology. This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

Recommended reading includes:
- Various: OWASP Guide to Building Secure Web Applications, available online
- O'Reilly, Loukides: Unix Power Tools, O'Reilly & Associates.
- Frisch: Essential System Administration, O'Reilly & Associates.
- NIST: Risk Management Guide for Information Technology Systems, available online as PDF
- BSI: IT-Grundschutzhandbuch, available online

- The lab allows flexible working since there are only few mandatory working during the semester.
- The lab covers a variety of different techniques. Thus, participating students should have a solid foundation in the following areas:
- Information security, operating system administration (especially Unix/Linux), and networking. Students are also expected to have a basic understanding of HTML, PHP, JavaScript, and MySQL because several examples are implemented in these languages.
- Students must be prepared to spend more than three hours per week to complete the lab assignments and the project. This applies particularly to students who do not meet the recommended requirements given above. Successful participants of the course receive 8 credits as compensation for their effort.
- All participants must sign the lab's charter and usage policy during the introduction lecture.

Prerequisites / notice
- The semester project is conducted under the supervision of a Computer Science professor.

### Minors

#### Minor in Computer Graphics

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>252-0546-00L</td>
<td>Physically-Based Simulation in Computer Graphics</td>
<td>W</td>
<td>5</td>
<td>2V+1U+1A</td>
<td>V. da Costa de Azevedo, B. Solenthaler, B. Thomaszewski</td>
</tr>
<tr>
<td>252-0543-01L</td>
<td>Computer Graphics</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>Does not take place this semester.</td>
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</table>

Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

Lecture notes
No
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
- Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition.

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Prerequisites / notice
- Mixed Reality topics are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Minor in Computer Vision

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<th>Number</th>
<th>Title</th>
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<tr>
<td>263-3210-00L</td>
<td>Deep Learning</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>F. Perez Cruz, A. Lucchi</td>
</tr>
</tbody>
</table>

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
- Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Computational Intelligence Lab: http://da.inf.ethz.ch/teaching/2019/CIL/.

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-118

Mixed Reality
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.

Objective
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Prerequisites / notice
- The programming assignments will be in C++. This will not be taught in the class.

Literature
- Books:
  - High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
  - Multiple view geometry in computer vision
  - Physically Based Rendering: From Theory to Implementation

Prerequisites / notice
- Visual Computing course recommended.
- The programming assignments will be in C++. This will not be taught in the class.
After attending this course, students will:

1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including: Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introduction to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course are student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMD research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites:
- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

#### Content

- Introduction to mixed reality technology
- Augmented Reality
- Virtual Reality
- 3D Computer Graphics
- 3D Computer Vision
- Human-Machine Interaction
- Mixed Reality

#### Objective

- Become familiar with important technical concepts and with concurrency folklore.
- Possibly large parallel high-performance software systems.
- Become able to distinguish parallelism in problem space and in machine space.

#### Prerequisites

- PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
- Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

#### Literature


#### Notice

- No lecture notes, but slides will be made available on the course webpage.

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### Minor in Data Management

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>263-2000-00L</td>
<td><strong>Design of Parallel and High-Performance Computing</strong></td>
<td>W</td>
<td>9</td>
<td>3V+2U+3A</td>
<td>T. Hoefler, M. Püschel</td>
</tr>
</tbody>
</table>

#### Abstract

Advanced topics in parallel and high-performance computing.

#### Objective

Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems.

Become able to distinguish parallelism in problem space and in machine space.

Become familiar with important technical concepts and with concurrency folklore.

#### Content

- We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms.
- We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free.
- We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

#### Prerequisites

- This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

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### Autumn Semester 2021

- **252-0535-00L Advanced Machine Learning**
- **263-2800-00L Design of Parallel and High-Performance Computing**
- **263-3010-00L Big Data**

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Objective

This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that’s 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today’s technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

Content

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

Literature

Large scale analytics and machine learning are outside of the scope of this course.

Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Prerequisites / notice

Number of participants limited to 320.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.

Abstract

Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, and databases and SQL.

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

263-3845-00L

Abstract
The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

Prerequisites / notice
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

263-3850-00L

Informal Methods
Formal methods are increasingly a key part of the methodological toolkit of systems programmers - those writing operating systems, databases, and distributed systems. This course is about how to apply concepts, techniques, and principles from formal methods to such software systems, and how to get into the habit of thinking formally about systems design even when writing low-level C code.

Objective
This course is about equipping students whose focus is systems with the insights and conceptual tools provided by formal methods, and thereby enabling them to become better systems programmers. By the end of the course, students should be able to seamlessly integrate basic concepts formal methods into how they conceive, design, implement, reason about, and debug computer systems.

Content
This course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written by students taking the course, and practical systems developed using formal techniques, in particular the verified seL4 microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).

Minor in Information Security

Number Title ECTS Hours Lecturers
252-0463-00L Security Engineering 7 2V+2A S. Krstic

Subject of the class are engineering techniques for developing secure systems. We examine concepts, methods and tools, applied within the different activities of the SW development process to improve security of the system. Topics: security requirements & risk analysis, system modeling & model-based development methods, implementation-level security, and evaluation criteria for secure systems.
Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software. Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

- security requirements & risk analysis,
- system modeling and model-based development methods,
- implementation-level security, and
- evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
   - "Risk": assets, threats, vulnerabilities, risk
   - Risk assessment: quantitative and qualitative
   - Safeguards
   - Generic risk analysis procedure
   - The OCTAVE approach
   - Example of qualitative risk assessment
11. Threat modeling
   - Overview
   - Safety engineering basics: FMEA and FTA
   - Security impact analysis in the design phase
   - Modeling security threats: attack trees
   - Examples and experience
12. Evaluation criteria
   - NIST special papers
   - ISO/IEC 27000
   - Common criteria
   - BSI baseline protection
13. Guest lecture
   - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites
Prerequisite: Class on Information Security

252-1411-00L Security of Wireless Networks W 6 credits 2V+1U+2A S. Capkun, K. Kostiainen

Abstract
Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.
Objective

After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

Content


252-1414-00L System Security W 7 credits 2V+2U+2A S. Capkun, A. Perrig

Abstract

The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective

- Students are familiar with fundamental network-security concepts.
- Students can implement network-security protocols based on cryptographic libraries.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Applied Cryptography".

Along the lectures, model cases will be elaborated and evaluated in the exercises.

263-4640-00L Network Security W 8 credits 2V+2U+3A A. Perrig, S. Frei, M. Legner, K. Paterson

Abstract

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

Objective

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content

The course will cover topics spanning four broad themes with a focus on the first two themes:
1. network defense mechanisms such as public-key infrastructures, TLS, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0086-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Taught competencies

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

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

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

263-4657-00L Advanced Encryption Schemes W 5 credits 2V+1U+1A R. Gay

Abstract

Public-Key Encryption has had a significant impact by enabling remote parties to communicate securely via an insecure channel. Latest schemes go further by providing a fine-grained access to the encrypted data.

Objective

The student is comfortable with formal security definitions and proof techniques used to analyze the security of the latest encryption schemes with advanced features. This prepares the student to start reading research papers on the field.

Content

We will start by presenting the notion of Public-Key Encryption with its various security guarantees and some constructions. Then we will look into encryption schemes with fine-grained access control to the encrypted data, such as identity-based encryption or attribute-based encryption and present different methodology to prove their security.

Literature

Links to relevant research papers will be given in the course materials.

Prerequisites / notice

It is recommended for students to have prior exposure to cryptography, e.g. the D-INFK course "Digital Signatures" or "Applied Cryptography".
Zero-Knowledge Proofs

Number of participants limited to 50.

Abstract
This course is a detailed introduction to zero-knowledge proof protocols.

Objective
To understand various methods of constructing zero-knowledge proof protocols, and be able to analyse their security properties.

Content
The course will discuss interactive zero-knowledge proofs based on various commitment schemes, and explore connections to other areas like secure multi-party computation. The course may also describe some more advanced constructions of non-interactive proofs.

Lecture notes
The course notes will be written in English.

Prerequisites / notice
No lecture notes, but slides will be made available on the course webpage.

ECTS
5 credits

2V+1U+1A

J. Bootle

Hardware Security

227-0579-00L

Abstract
This course covers the security of commodity computer hardware (e.g., CPU, DRAM, etc.) with a special focus on cutting-edge hands-on research. The aim of the course is familiarizing the students with hardware security and more specifically microarchitectural and circuit-level attacks and defenses through lectures, reviewing and discussing papers, and executing some of these advanced attacks.

Objective
By the end of the course, the students will be familiar with the art in commodity computer hardware attacks and defenses. More specifically, the students will learn about:

- security problems of commodity hardware that we use everyday and how you can defend against them.
- relevant computer architecture and operating system aspects of these issues.
- hands-on techniques for performing hardware attacks.
- writing critical reviews and constructive discussions with peers on this topic.

This is the course where you get credit points by building some of the most advanced exploits on the planet! The luckiest team will collect a Best Demo Award at the end of the course.

Literature
Slides, relevant literature and manuals will be made available during the course.

Prerequisites / notice
Knowledge of systems programming and computer architecture is a plus.

Minor in Machine Learning

Number
Title
Type
ECTS
Hours
Lecturers

252-0535-00L
Advanced Machine Learning
W
10 credits
3V+2U+4A
J. M. Buhmann, C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
Students should have taken a first course in Cryptography (as taught in the Information Security course at Bachelor’s level). Confidence with algebra and probability is desirable.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Natural Language Processing

252-3005-00L

Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.
Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-2400-00L Reliable and Trustworthy Artificial Intelligence W 6 credits 2V+2U+1A M. Vechev

Abstract
Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting advances that bring us closer to constructing such models.

Objective
The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.

Content
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of a safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

- Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
- Defenses against attacks
- Combining gradient-based optimization with logic for encoding background knowledge
- Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
- Probabilistic certification of deep neural networks
- Training deep neural networks to be provably robust via automated reasoning
- Fairness (different notions of fairness, certifiably fair representation learning)
- Federated Learning (introduction, security considerations)

Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

For solving assignments, some programming experience in Python is expected.

263-3210-00L Deep Learning W 8 credits 3V+2U+2A F. Perez Cruz, A. Lucchi

Number of participants limited to 320.

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Content
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://las.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://ml2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/s19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

Prerequisites
Number of participants limited to 75.

Necessary Mathematics
- Multivariate calculus
- Linear algebra
- Probability theory

Recommended Programming
- Python

Prerequisites
This is an advanced level course that requires some background in machine learning. More importantly, students are expected to have a very solid background in mathematics. The course will make heavy use of mathematics and is not meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

263-5005-00L Artificial Intelligence in Education W 5 credits 2V+1U+1A M. Sachan, T. Sinha

Number of participants limited to 75.

Abstract
Artificial Intelligence (AI) methods have shown to have a profound impact in educational technologies, where the great variety of tasks and data types enable us to get benefit of AI techniques in many different ways. We will review relevant methods and applications of AI in various educational technologies, and work on problem sets and projects to solve problems in education with the help of AI.

Objective
The course will be centered around exploring methodological and system-focused perspectives on designing AI systems for education and analyzing educational data using AI methods. Students will be expected to a) engage in presentations and active in-class discussion, b) work on problem-sets exemplifying the use of educational data mining techniques, and c) undertake a final course project with feedback from instructors.

Content
The course will start with a general introduction to AI, where we will cover supervised and unsupervised learning techniques (e.g., classification and regression models, feature selection and preprocessing of data, clustering, dimensionality reduction and text mining techniques) with a focus on application of these techniques in educational data mining. After the introduction of the basic methodologies, we will continue with the most relevant applications of AI in educational technologies (e.g., intelligent tutoring and student personalization, scaffolding open-ended discovery learning, socially-aware AI and learning at scale with AI systems). In the final part of the course, we will cover challenges associated with using AI in student facing settings.

Lecture notes
Lecture slides will be made available at the course Web site.

Literature
No textbook is required, but there will be regularly assigned readings from research literature, linked to the course website.
There are no prerequisites for this class. However, it will help if the student has taken an undergraduate or graduate level class in statistics, data science or machine learning. This class is appropriate for advanced undergraduates and master students in Computer Science as well as PhD students in other departments.

263-5210-00L Probabilistic Artificial Intelligence  
**W** 8 credits 3V+2U+2A A. Krause

**Abstract**
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

**Objective**
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

**Content**
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

**Prerequisites / notice**
Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course “Introduction to Machine Learning” is considered as a prerequisite.

263-5255-00L Foundations of Reinforcement Learning  
**W** 5 credits 2V+2A N. He

**Abstract**
Reinforcement learning (RL) has been in the limelight of many recent breakthroughs in artificial intelligence. This course focuses on theoretical and algorithmic foundations of reinforcement learning, through the lens of optimization, modern approximation, and learning theory. The course targets M.S. students with strong research interests in reinforcement learning, optimization, and control.

**Objective**
This course aims to provide students with an advanced introduction of RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, students will be able to:
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover “new” applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

**Content**
Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

**Lecture notes**
Lecture notes will be posted on Moodle.

**Literature**
Dynamic Programming and Optimal Control, Vol I & II, Dimitris Bertsekas
Algorithms for Reinforcement Learning, Csaba Czepesvári.

**Prerequisites / notice**
Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

### Minor in Networking

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-1411-00L</td>
<td>Security of Wireless Networks</td>
<td>W</td>
<td>6</td>
<td>2V+1U+2A</td>
<td>S. Capkun, K. Kostiainen</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.</td>
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| 263-4640-00L | Network Security | W    | 8     | 2V+2U+3A | A. Perrig, S. Frei, M. Legner, K. Paterson |
| **Abstract** | Some of today’s most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them. |
| **Objective** | Students are familiar with fundamental network-security concepts. Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures. Students can identify and assess vulnerabilities in software systems and network protocols. Students have an in-depth understanding of a range of important state-of-the-art security technologies. Students can implement network-security protocols based on cryptographic libraries. |
| **Content** | The course will cover topics spanning four broad themes with a focus on the first two themes: (1) network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems; (2) network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks; (3) analysis and inference topics such as traffic monitoring and network forensics; and (4) new technologies related to next-generation networks. In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics. |
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

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

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

### Prerequisites / notice

Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

### Literature

Lecture notes and material will be made available before each course on the course website. Relevant references will be made available through the course website.

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

**Domain C - Social Competencies**
- Communication
- Cooperation and Teamwork

**Domain D - Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

### Course Information

**227-0575-00L Advanced Topics in Communication Networks**

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<tr>
<th>W</th>
<th>6 credits</th>
<th>2V+2U</th>
<th>L. Vanbever</th>
</tr>
</thead>
</table>

**Abstract**

This course covers advanced topics and technologies in computer networks, both theoretically and practically. It is offered each Fall semester, with rotating topics. Repetition for credit is possible with consent of the instructor. In the Fall 2021, the course will cover advanced topics in Internet routing and forwarding.

**Objective**

The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet routing and forwarding technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments, and even implement some of them on their own during labs and a final group project.

**Content**

The course will cover advanced topics in Internet routing and forwarding such as:

- Tunneling
- Hierarchical routing
- Traffic Engineering and Load Balancing
- Virtual Private Networks
- Quality of Service/Queuing/Scheduling
- Fast Convergence
- Network virtualization
- Network programmability (OpenFlow, P4)
- Network measurements

The course will be divided in two main blocks. The first block (~8 weeks) will interleave classical lectures with practical exercises and labs. The second block (~6 weeks) will consist of a practical project which will be performed in small groups (~3 students). During the second block, lecture slots will be replaced by feedback sessions where students will be able to ask questions and get feedback about their project. The last week of the semester will be dedicated to student presentations and demonstrations.

**Lecture notes**

Lecture notes and material will be made available before each course on the course website.

**Prerequisites / notice**

Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

### Minor in Programming Languages and Software Engineering

#### Number Title

| 252-0237-00L | Concepts of Object-Oriented Programming |

Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

**Abstract**

Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

**Objective**

After this course, students will:

- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and software environments. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing).
- The key problems of single and multiple inheritance and how different languages address them.
- Generic type systems, in particular, Java generics, C# generics, and C++ templates.
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them.
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing.
- How to maintain the consistency of data structures.

We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems. In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dracae, ...), cryptograhpic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.
Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses “Parallele Programmierung (parallel programming)” and “Algorithmen und Datenstrukturen (algorithm and data structures)” or equivalent courses.

263-3845-00L Data Management Systems W 8 credits 3V+1U+3A G. Alonso
Abstract
The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

Prerequisites / notice
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

263-3850-00L Informal Methods W 5 credits 2G+2A D. Cock
Abstract
Formal methods are increasingly a key part of the methodological toolkit of systems programmers - those writing operating systems, databases, and distributed systems. This course is about how to apply concepts, techniques, and principles from formal methods to such software systems, and how to get into the habit of thinking formally about systems design even when writing low-level C code.

Objective
This course is about equipping students whose focus is systems with the insights and conceptual tools provided by formal methods, and thereby enabling them to become better systems programmers.

Content
By the end of the course, students should be able to seamlessly integrate basic concepts form formal methods into how they conceive, design, implement, reason about, and debug computer systems.

The goal is not to provide a comprehensive introduction to formal methods - this is well covered by other courses in the department. Instead, it is intended to provide students in computer systems (who may or may not have existing background knowledge of formal methods) with a basis for applying formal methods in their work.

The course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written both by students taking the course, and practical systems developed using formal techniques, in particular the verified seL4 microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).

Minor in Theoretical Computer Science

Number Title Type ECTS Hours Lecturers
252-0417-00L Randomized Algorithms and Probabilistic Methods W 10 credits 3V+2U+4A A. Steger
Abstract
Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks
Objective
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.
Content
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Lecture notes
Yes
Literature

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez
Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.
Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-1407-00L Algorithmic Game Theory W 7 credits 3V+2U+1A P. Penna

Abstract
Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all. Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

Outline:
- Introduction to classic game-theoretic concepts.
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity.
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization.
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the 'Price of Anarchy').
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium.
- Selected current research topics, such as Google's Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

Lecture notes
Lecture notes will be usually posted on the website shortly after each lecture.


"Game Theory and Strategy", Philip D. Straffin, The Mathematical Association of America, 5th printing, 2004

Prerequisites / notice
Several copies of both books are available in the Computer Science library.

Requirements: You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

Audience: Although this is a Computer Science course, we encourage the participation from all students who are interested in this topic.

252-1425-00L Geometry: Combinatorics and Algorithms W 8 credits 3V+2U+2A B. Gärtner, E. Welzl, M. Hoffmann, M. Wettstein

Abstract
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

Objective
The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Content
Planar and geometric graphs, embeddings and their representation (Whitney’s Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan’s Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.
Lectures will be on the blackboard only, but there will be a set of typeset lecture notes which follow the class closely.

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

**Outlook:** In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

**263-4500-00L Advanced Algorithms**

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<tr>
<th>W</th>
<th>9 credits</th>
<th>3V+2U+3A</th>
<th>M. Ghaffari, G. Zuzic</th>
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</table>

**Abstract**

This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Objective**

This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design. The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

**Lecture notes**

https://people.inf.ethz.ch/gmohsen/AA21/

**Prerequisites / notice**

Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you’re ready for this class or not, please consult the instructor.

**401-3055-64L Algebraic Methods in Combinatorics**

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<th>W</th>
<th>6 credits</th>
<th>2V+1U</th>
<th>B. Sudakov</th>
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</table>

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**

The course will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

**Lecture notes**

https://people.inf.ethz.ch/gmohsen/AA21/

**Prerequisites / notice**

This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Students are expected to have a mathematical background and should be able to write rigorous proofs.

**401-3901-00L Linear & Combinatorial Optimization**

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<tr>
<th>W</th>
<th>11 credits</th>
<th>4V+2U</th>
<th>R. Zenklusen</th>
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</table>

**Abstract**

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**

- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**


**Prerequisites / notice**

Solid background in linear algebra.

Former course title: Mathematical Optimization.
Elective Courses (only for Programme Regulations 2020)

Students can individually choose from the entire Master course offerings from ETH Zurich, EPF Lausanne, the University of Zurich and - but only with the consent of the Director of Studies - from all other Swiss universities.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-0293-00L</td>
<td>Wireless Networking and Mobile Computing</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>S. Mangold</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course gives an overview about wireless standards and summarizes the state of art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, including new topics such as contact tracing with Bluetooth, audio communication, cognitive radio, visible light communications. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication.</td>
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<tr>
<td><strong>Content</strong></td>
<td>New: Starting 2020, we will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth.</td>
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<td><strong>Lecture notes</strong></td>
<td>The course material will be made available by the lecturer.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>(1) The course webpage (look for Stefan Mangold's site)</td>
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<td>(2) The Java 802 protocol emulator &quot;JEmula802&quot; from <a href="https://bitbucket.org/lfield/jemula802">https://bitbucket.org/lfield/jemula802</a></td>
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<td><strong>Prerequisites / notice</strong></td>
<td>Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).</td>
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<td>263-0600-00L</td>
<td>Research in Computer Science Only for Computer Science MSc.</td>
<td>W</td>
<td>5 credits</td>
<td>11A</td>
<td>Professors</td>
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<td><strong>Abstract</strong></td>
<td>Independent project work under the supervision of a Computer Science Professor.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Independent project work under the supervision of a Computer Science Professor.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Only students who fulfill one of the following requirements are allowed to begin a research project: a) 1 lab (interfocus course) and 1 focus course b) 2 core focus courses c) 2 labs (interfocus courses)</td>
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<td>A task description must be submitted to the Student Administration Office at the beginning of the work.</td>
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<td>227-2210-00L</td>
<td>Computer Architecture</td>
<td>W</td>
<td>8 credits</td>
<td>6G+1A</td>
<td>O. Mutlu</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Computer architecture is the science &amp; art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.</td>
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<td><strong>Objective</strong></td>
<td>We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g. genome analysis, biomolecules, climate models, machine learning), etc.</td>
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<td><strong>Content</strong></td>
<td>The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>All the materials (including lecture slides) will be provided on the course website: <a href="https://safari.ethz.ch/architecture/">https://safari.ethz.ch/architecture/</a></td>
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<td>The video recordings of the lectures are expected to be made available after lectures.</td>
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</table>
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective:

- Gain hands-on-experience with real products and the latest technology in distributed systems.

8 credits: 2V+2U+2A

System Security

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, memory analytics, bioinformatics, machine learning), etc.

- prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

The course takes a hardware/software cooperative approach to understanding and designing computer systems.

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g., graph analytics, bioinformatics, machine learning), etc.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

The list of papers will be provided at the beginning of the course.

The main source of information for the course will be articles and research papers describing the architecture of the systems discussed. The list of papers will be provided at the beginning of the course.

The course involves the participation in a substantial development and/or evaluation project involving distributed systems technology. There is no lecture associated to the course.

There are projects available in a wide range of areas: from web services to ubiquitous computing including as well wireless networks, ad-hoc networks, RFID, and distributed applications on smartphones.

The goal of the project is for the students to gain hands-on-experience with real products and the latest technology in distributed systems. There is no lecture associated to the course.

All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics

W 5 credits 2G+2A  D. Cock
ECTS

The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, specialized processors) in particular.

This course covers topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

This course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written both by students taking the course, and practical systems developed using formal techniques, in particular the verified sel4 microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).

Number  Title  Type ECTS  Hours  Lecturers
263-3504-00L  Hardware Acceleration for Data Processing  W  2 credits  2S  G. Alonso

Abstract  The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Objective  The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Content  The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, high performance computing, data appliances, and data centers.

Prerequisites / notice  Students taking this seminar should have the necessary background in systems and low level programming.

Number  Title  Type ECTS  Hours  Lecturers
252-0535-00L  Advanced Machine Learning  W  10 credits  3V+2U+4A  J. M. Buhmann, C. Cotrini Jimenez

Abstract  Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective  Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content  The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:  What is data?  Bayesian Learning  Computational learning theory

Supervised learning:  Ensembles: Bagging and Boosting  Max Margin methods  Neural networks

Unsupervised learning:  Dimensionality reduction techniques  Clustering  Mixture Models  Non-parametric density estimation  Learning Dynamical Systems

Lecture notes  No lecture notes, but slides will be made available on the course webpage.
The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.

To facilitate deeper understanding, an important part of the course will be a group hands-on programming project where students will build a system based on the learned material.
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and communication. This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics. The course is designed for graduate students. For solving assignments, some programming experience in Python is expected.

### Seminar in Visual Computing

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<tr>
<td>263-3713-00L</td>
<td>Advanced Topics in Human-Centric Computer Vision Numbers of participants limited to 20.</td>
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The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

In this seminar we will discuss state-of-the-art literature on human-centric computer vision topics including but not limited to human pose estimation, hand and eye-gaze estimation as well as generative modeling of detailed human activities.

The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

- Presenter: Give a presentation about the paper that you read in depth.
- Reviewer: Perform a critical review of the paper.
- All other students: read the paper and submit questions they have about the paper before the presentation.

Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Prerequisites / notice

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<th>Taught competencies</th>
<th>Analytical Competencies</th>
<th>Communication</th>
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<th>Critical Thinking</th>
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<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning Number of participants limited to 40.</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>J. M. Buhmann, R. Cotterell, J. Vogt, F. Yang</td>
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The deadline for deregistering expires at the end of the fourth week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.

The seminar “Advanced Topics in Machine Learning” familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while omitting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.
The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

The papers will be presented in the first session of the seminar.

This seminar covers advanced topics in computer graphics, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support through various language features. After this course, students will:

- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.
- Understand language design and be able to design new languages.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.

The seminars will be announced in the lecture.


The topics discussed in the course include among others:

- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them
- Generic type systems, in particular, Java generics, C# generics, and C++ templates
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
- How to maintain the consistency of data structures
Objective

Security engineering is an evolving discipline that unifies two important areas: software engineering and security. Software Engineering addresses the development and application of methods for systematically developing, operating, and maintaining, complex, high-quality software.

Security, on the other hand, is concerned with assuring and verifying properties of a system that relate to confidentiality, integrity, and availability of data.

The goal of this class is to survey engineering techniques for developing secure systems. We will examine concepts, methods, and tools that can be applied within the different activities of the software development process, in order to improve the security of the resulting systems.

Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems
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Topics covered include

* security requirements & risk analysis,
* system modeling and model-based development methods,
* implementation-level security, and
* evaluation criteria for the development of secure systems

Modules taught:

1. Introduction
   - Introduction of Infsec group and speakers
   - Security meets SW engineering: an introduction
   - The activities of SW engineering, and where security fits in
   - Overview of this class
2. Requirements Engineering: Security Requirements and some Analysis
   - Overview: functional and non-functional requirements
   - Use cases, misuse cases, sequence diagrams
   - Safety and security
3. Modeling in the design activities
   - Structure, behavior, and data flow
   - Class diagrams, statecharts
4. Model-driven security for access control (Part I)
   - SecureUML as a language for access control
   - Combining Design Modeling Languages with SecureUML
   - Semantics, i.e., what does it all mean,
   - Generation
   - Examples and experience
5. Model-driven security (Part II)
   - Continuation of above topics
6. Security patterns (design and implementation)
7. Implementation-level security
   - Buffer overflows
   - Input checking
   - Injection attacks
8. Code scanning
   - Static code analysis basics
   - Theoretical and practical challenges
   - Analysis algorithms
   - Common bug pattern search and specification
   - Dataflow analysis
9. Testing
   - Overview and basics
   - Model-based testing
   - Testing security properties
10. Risk analysis and management
    - "Risk": assets, threats, vulnerabilities, risk
    - Risk assessment: quantitative and qualitative
    - Safeguards
    - Generic risk analysis procedure
    - The OCTAVE approach
    - Example of qualitative risk assessment
11. Threat modeling
    - Overview
    - Safety engineering basics: FMEA and FTA
    - Security impact analysis in the design phase
    - Modeling security threats: attack trees
    - Examples and experience
12. Evaluation criteria
    - NIST special papers
    - ISO/IEC 27000
    - Common criteria
    - BSI baseline protection
13. Guest lecture
    - TBA

Literature
- Further relevant books and journal/conference articles will be announced in the lecture.

Prerequisites / notice
Prerequisite: Class on Information Security

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez
Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real-world data.

Topics covered in the lecture include:

- Fundamentals:
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- Supervised learning:
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- Unsupervised learning:
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

252-1414-00L  System Security  W  7 credits  2V+2U+2A  S. Čapkun, A. Perrig

Abstract
The first part of the lecture covers individual system aspects starting with tamper-proof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.

Content
The first part of the lecture covers individual system's aspects starting with tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TCG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

263-2800-00L  Design of Parallel and High-Performance Computing  W  9 credits  3V+2U+3A  T. Hoefler, M. Püschel

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

263-3010-00L  Big Data  W  10 credits  3V+2U+4A  G. Fourny

Abstract
The key challenge of the information society is to turn data into information, information into knowledge, knowledge into value. This has become increasingly complex. Data comes in larger volumes, diverse shapes, from different sources. Data is more heterogeneous and less structured than forty years ago. Nevertheless, it still needs to be processed fast, with support for complex operations.
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective. This combination of requirements, together with the technologies that have emerged in order to address them, is typically referred to as "Big Data." This revolution has led to a completely new way to do business, e.g., develop new products and business models, but also to do science -- which is sometimes referred to as data-driven science or the "fourth paradigm".

Unfortunately, the quantity of data produced and available -- now in the Zettabyte range (that's 21 zeros) per year -- keeps growing faster than our ability to process it. Hence, new architectures and approaches for processing it were and are still needed. Harnessing them must involve a deep understanding of data not only in the large, but also in the small.

The field of databases evolves at a fast pace. In order to be prepared, to the extent possible, to the (r)evolutions that will take place in the next few decades, the emphasis of the lecture will be on the paradigms and core design ideas, while today's technologies will serve as supporting illustrations thereof.

After visiting this lecture, you should have gained an overview and understanding of the Big Data landscape, which is the basis on which one can make informed decisions, i.e., pick and orchestrate the relevant technologies together for addressing each business use case efficiently and consistently.

This course gives an overview of database technologies and of the most important database design principles that lay the foundations of the Big Data universe. We take the monolithic, one-machine relational stack from the 1970s, smash it down and rebuild it on top of large clusters: starting with distributed storage, and all the way up to syntax, models, validation, processing, indexing, and querying. A broad range of aspects is covered with a focus on how they fit all together in the big picture of the Big Data ecosystem.

No data is harmed during this course, however, please be psychologically prepared that our data may not always be in third normal form.

- physical storage: distributed file systems (HDFS), object storage(S3), key-value stores
- logical storage: document stores (MongoDB), column stores (HBase), graph databases (neo4j), data warehouses (ROLAP)
- data formats and syntaxes (XML, JSON, RDF, Turtle, CSV, XBRL, YAML, protocol buffers, Avro)
- data shapes and models (tables, trees, graphs, cubes)
- type systems and schemas: atomic types, structured types (arrays, maps), set-based type systems (?, *, +)
- an overview of functional, declarative programming languages across data shapes (SQL, XQuery, JSONiq, Cypher, MDX)
- the most important query paradigms (selection, projection, joining, grouping, ordering, windowing)
- paradigms for parallel processing, two-stage (MapReduce) and DAG-based (Spark)
- resource management (YARN)
- what a data center is made of and why it matters (racks, nodes, ...)
- underlying architectures (internal machinery of HDFS, HBase, Spark, neo4j)
- optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- applications.

- The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, optimization techniques (functional and declarative paradigms, query plans, rewrites, indexing)
- The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.
- The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.
- The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understating these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Large scale analytics and machine learning are outside of the scope of this course. Papers from scientific conferences and journals. References will be given as part of the course material during the semester.

This course, in the autumn semester, is only intended for:
- Computer Science students
- Data Science students
- CBB students with a Computer Science background

Mobility students in CS are also welcome and encouraged to attend. If you experience any issue while registering, please contact the study administration and you will be gladly added.

For students of all other departements interested in this fascinating topic: I would love to have you visit my lectures as well! So there is a series of two courses specially designed for you:
- "Information Systems for Engineers" (SQL, relational databases): this Fall
- "Big Data for Engineers" (similar to Big Data, but adapted for non Computer Scientists): Spring 2021

There is no hard dependency, so you can either them in any order, but it may be more enjoyable to start with Information Systems for Engineers.

Students who successfully completed Big Data for Engineers are not allowed to enrol in the course Big Data.
Network Security

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems.

This course provides an in-depth study of network attack techniques and methods to defend against them.

- Students are familiar with fundamental network-security concepts.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

The course will cover topics spanning four broad themes with a focus on the first two themes:
(1) network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
(2) network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
(3) analysis and inference topics such as traffic monitoring and network forensics; and
(4) new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice
This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Tuited competencies

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

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

Domain C - Social Competencies
- Communication
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

Domain D - Personal Competencies
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

- Self-direction and Self-management

263-5902-00L Computer Vision

The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

263-0007-00L Computational Systems Biology

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective
The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content
Biological networks have witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label “Systems Biology”, focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes
http://www.csb.ethz.ch/education/lectures.html
Lecturers
The Applied Security Laboratory addresses four major topics: operating system security (hardening, vulnerability scanning, access control, and configuration security mechanisms, risk analysis, system review).

Objective
At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and information security, operating system security, OS hardening, computer forensics, web application security, project work, design, numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

Content
This course covers fundamentals of modern computer graphics. Students will learn about 3D object representations, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

Literature

Prerequisites / notice
The students will also complete an independent project: based on a set of functional requirements, they will design and implement a prototypical IT system. In addition, they will conduct a thorough security analysis and devise appropriate security measures for their systems. Finally, they will carry out a technical and conceptual review of another system. All project work will be performed in teams and must be properly documented.

Lecture notes

Literature
Recommended reading includes:
* Garfinkel, Schwartz, Safford: Practical Unix & Internet Security, O'Reilly & Associates
* Various: OWASP Guide to Building Secure Web Applications, available online
* O'Reilly, Louikides: Unix Power Tools, O'Reilly & Associates.
* Frisch: Essential System Administration, O'Reilly & Associates.
* NIST: Risk Management Guide for Information Technology Systems, available online as PDF
* BSI: IT-Grundschutzhandbuch, available online

Prerequisites / notice
* The lab allows flexible working since there are only few mandatory meetings during the semester.
* The lab covers a variety of different techniques. Thus, participating students should have a solid foundation in the following areas: information security, operating system administration (especially Unix/Linux), and networking. Students are also expected to have a basic understanding of HTML, PHP, JavaScript, and MySQL because several examples are implemented in these languages.
* Students must be prepared to spend more than three hours per week to complete the lab assignments and the project. This applies particularly to students who do not meet the recommended requirements given above. Successful participants of the course receive 8 credits as compensation for their effort.
* All participants must sign the lab’s charter and usage policy during the introduction lecture.

This course involves the participation in a substantial development and/or evaluation project involving distributed systems technology. There are projects available in a wide range of areas: from web services to ubiquitous computing including wireless networks, ad-hoc networks, RFID, and distributed applications on smartphones.

**Objective**
Gain hands-on-experience with real products and the latest technology in distributed systems.

**Content**
This course involves the participation in a substantial development and/or evaluation project involving distributed systems technology. There are projects available in a wide range of areas: from web services to ubiquitous computing including as well wireless networks, ad-hoc networks, and distributed application on smartphones. The goal of the project is for the students to gain hands-on-experience with real products and the latest technology in distributed systems. There is no lecture associated to the course.

### 252-1407-00L Algorithmic Game Theory

**Abstract**
Game theory provides a formal model to study the behavior and interaction of self-interested users and programs in large-scale distributed computer systems without central control. The course discusses algorithmic aspects of game theory.

**Objective**
Learning the basic concepts of game theory and mechanism design, acquiring the computational paradigm of self-interested agents, and using these concepts in the computational and algorithmic setting.

**Content**
The Internet is a typical example of a large-scale distributed computer system without central control, with users that are typically only interested in their own good. For instance, they are interested in getting high bandwidth for themselves, but don't care about others, and the same is true for computational load or download rates. Game theory provides a mathematical model for the behavior and interaction of such selfish users and programs. Classic game theory dates back to the 1930s and typically does not consider algorithmic aspects at all.

Only a few years back, algorithms and game theory have been considered together, in an attempt to reconcile selfish behavior of independent agents with the common good.

This course discusses algorithmic aspects of game-theoretic models, with a focus on recent algorithmic and mathematical developments. Rather than giving an overview of such developments, the course aims to study selected important topics in depth.

**Outline:**
- Introduction to classic game-theoretic concepts.
- Existence of stable solutions (equilibria), algorithms for computing equilibria, computational complexity.
- Speed of convergence of natural game playing dynamics such as best-response dynamics or regret minimization.
- Techniques for bounding the quality-loss due to selfish behavior versus optimal outcomes under central control (a.k.a. the 'Price of Anarchy').
- Design and analysis of mechanisms that induce truthful behavior or near-optimal outcomes at equilibrium.
- Selected current research topics, such as Google's Sponsored Search Auction, the U.S. FCC Spectrum Auction, Kidney Exchange.

**Lecture notes**
Lecture notes will be usually posted on the website shortly after each lecture.

**Literature**

"Game Theory and Strategy", Philip D. Straffin, The Mathematical Association of America, 5th printing, 2004

**Prerequisites / notice**
Several copies of both books are available in the Computer Science library.

**Audience:**
Anyone aged 21 or older who wishes to participate in the course.

**Requirements:**
You should enjoy precise mathematical reasoning. You need to have passed a course on algorithms and complexity. No knowledge of game theory is required.

### 252-1411-00L Security of Wireless Networks

**Abstract**
Core Elements: Wireless communication channel, Wireless network architectures and protocols, Attacks on wireless networks, Protection techniques.

**Objective**
After this course, the students should be able to: describe and classify security goals and attacks in wireless networks; describe security architectures of the following wireless systems and networks: 802.11, GSM/UMTS, RFID, ad hoc/sensor networks; reason about security protocols for wireless network; implement mechanisms to secure 802.11 networks.

**Content**

### 252-1425-00L Geometry: Combinatorics and Algorithms

**Abstract**
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

**Objective**
The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.

**Content**
Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Deauhany triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

**Prerequisites / notice**
Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

**Outlook:**
In the following spring semester there is a seminar "Geometry: Combinatorics and Algorithms" that builds on this course. There are ample possibilities for Semester-, Bachelor- and Master Thesis projects in the area.

### 227-2210-00L Computer Architecture

**Abstract**
Computer architecture is the science & art of designing and optimizing hardware components and the hardware/software interface to create a computer that meets design goals. This course covers basic components of a modern computing system (memory, processors, interconnects, accelerators). The course takes a hardware/software cooperative approach to understanding and designing computing systems.
Objective

We will learn the fundamental concepts of the different parts of modern computing systems, as well as the latest major research topics in Industry and Academia. We will extensively cover memory systems (including DRAM and new Non-Volatile Memory technologies, memory controllers, flash memory), parallel computing systems (including multicore processors, coherence and consistency, GPUs), heterogeneous computing, processing-in-memory, interconnection networks, specialized systems for major data-intensive workloads (e.g., graph analytics, bioinformatics, machine learning), etc.

Content

The principles presented in the lecture are reinforced in the laboratory through 1) the design and implementation of a cycle-accurate simulator, where we will explore different components of a modern computing system (e.g., pipeline, memory hierarchy, branch prediction, prefetching, caches, multithreading), and 2) the extension of state-of-the-art research simulators (e.g., Ramulator) for more in-depth understanding of specific system components (e.g., memory scheduling, prefetching).

Lecture notes

All the materials (including lecture slides) will be provided on the course website: https://safari.ethz.ch/architecture/

The video recordings of the lectures are expected to be made available after lectures.

Literature

We will provide required and recommended readings in every lecture. They will mainly consist of research papers presented in major conferences and journals. In addition, we will extensively use textbooks such as the one by Jurafsky and Martin. The main objective is to familiarize students with this emerging technology. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice

This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inl.ethz.ch/teaching/reliableai21).

- Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
- Defenses against attacks
- Combining gradient-based optimization with logic for encoding background knowledge
- Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
- Probabilistic certification of deep neural networks
- Training deep neural networks to be provably robust via automated reasoning
- Fairness (different notions of fairness, certifiably fair representation learning)
- Federated Learning (introduction, security considerations)

For solving assignments, some programming experience in Python is expected.

Prerequisites / notice

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

Number of participants limited to 400.

Prerequisites / notice

For solving assignments, some programming experience in Python is expected.

Prerequisites / notice

Number of participants limited to 320.
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following conditions:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://las.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://ml2.inf.ethz.ch/courses/slt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

263-3850-00L Informal Methods W 5 credits 2G+2A D. Cock

Abstract
Formal methods are increasingly a key part of the methodological toolkit of systems programmers - those writing operating systems, databases, and distributed systems. This course is about how to apply concepts, techniques, and principles from formal methods to such software systems, and how to get into the habit of thinking formally about systems design even when writing low-level C code.

Objective
This course is about equipping students whose focus is systems with the insights and conceptual tools provided by formal methods, and thereby enabling them to become better systems programmers.

By the end of the course, students should be able to seamlessly integrate basic concepts form formal methods into how they conceive, design, implement, reason about, and debug computer systems.

Content
The goal is not to provide a comprehensive introduction to formal methods - this is well covered by other courses in the department. Instead, it is intended to provide students in computer systems (who may or may not have existing background knowledge of formal methods) with a basis for applying formal methods in their work.

This course does not assume prior knowledge of formal methods, and will start with a quick review of topics such static vs. dynamic reasoning, variants and invariants, program algebra and refinement, etc. However, it is strongly recommended that students have already taken one of the introductory formal methods course at ETH (or equivalents elsewhere) before taking this course - the emphasis is on reinforcing these concepts by applying them, not to teach them from scratch.

Instead, the majority of the course will be about how to apply these techniques to actual, practical code in real systems. We will work from real systems code written both by students taking the course, and practical systems developed using formal techniques, in particular the verified seL4 microkernel will be a key case study. We will also focus on informal, pen-and-paper arguments for correctness of programs and systems rather than using theorem provers or automated verification tools; again these latter techniques are well covered in other courses (and recommended as a complement to this one).

263-4500-00L Advanced Algorithms W 9 credits 3V+2U+3A M. Ghaffari, G. Zuzic

Abstract
This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

Objective
This course familiarizes the students with some of the main tools and techniques in modern subareas of algorithm design.

Content
The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, streaming algorithms, sketching algorithms, and derandomization.

Lecture notes
https://people.inf.ethz.ch/gmohsen/AAt21/

Prerequisites / notice
This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you're ready for this class or not, please consult the instructor.

263-5210-00L Probabilistic Artificial Intelligence W 8 credits 3V+2U+2A A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming. The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

263-5905-00L Mixed Reality W 5 credits 3G+1A I. Armeni, F. Bogo, M. Pollefeys

Abstract
The goal of this course is an introduction and hands-on experience on latest mixed reality technology at the cross-section of 3D computer graphics and vision, human machine interaction, as well as gaming technology.
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including:

- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are
recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

Prerequisites / notice


261-5100-00L Computational Biomedicine W 5 credits 2V+1U+1A V. Boeva, G. Rätsch

Objective

After attending this course, students will:

1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction

2. Have a clear understanding on how to build mixed reality apps

3. Have a good overview of state-of-the-art Mixed Reality

Content

The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including:

- Introduction to Mixed Reality / Augmented Reality / Virtual Reality Introdution to 3D Computer Graphics, 3D Computer Vision. This will take place in the form of short lectures, followed by student presentations discussing the current state-of-the-art. The main focus of this course is student projects on mixed reality topics, where small groups of students will work on a particular project with the goal to design, develop and deploy a mixed reality application. The project topics are flexible and can reach from proof-of-concept vision/graphics/HMI research, to apps that support teaching with interactive augmented reality, or game development. The default platform will be Microsoft HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

Prerequisites / notice

Prerequisites include:

- Good programming skills (C# / C++ / Java etc.)
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.

227-0575-00L Advanced Topics in Communication Networks W 6 credits 2V+2U L. Vanbever

Abstract

This course covers advanced topics and technologies in computer networks, both theoretically and practically. It is offered each Fall semester, with rotating topics. Repetition for credit is possible with consent of the instructor. In the Fall 2021, the course will cover advanced topics in Internet routing and forwarding.

Objective

The goals of this course is to provide students with a deeper understanding of the existing and upcoming Internet routing and forwarding technologies used in large-scale computer networks such as Internet Service Providers (e.g., Swisscom or Deutsche Telekom), Content Delivery Networks (e.g., Netflix) and Data Centers (e.g., Google). Besides covering the fundamentals, the course will be "hands-on" and will enable students to play with the technologies in realistic network environments, and even implement some of them on their own during labs and a final group project.

Content

The course will cover advanced topics in Internet routing and forwarding such as:

- Tunneling
- Hierarchical routing
- Traffic Engineering and Load Balancing
- Virtual Private Networks
- Quality of Service/Queueing/Scheduling
- Fast Convergence
- Network virtualization
- Network programmability (OpenFlow, P4)
- Network measurements

Lecture notes

Lecture notes and material will be made available before each course on the course website.

Literature

Relevant references will be made available through the course website.

Prerequisites / notice

Prerequisites: Communication Networks (227-0120-00L) or equivalents / good programming skills (in any language) are expected as both the exercises and the final project will involve coding.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

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

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking

401-3901-00L Linear & Combinatorial Optimization W 11 credits 4V+2U R. Zenklusen

Abstract

Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective

The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Computational Biology**

Lecturers
- S. Capkun

ECTS
- 2 credits

**Current Topics in Information Security**


Solid background in linear algebra.

**Prerequisites / notice**

**Taught competencies**
- Former course title: Mathematical Optimization.
- Concepts and Theories assessed
- Techniques and Technologies not assessed
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies not assessed
- Problem-solving assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Critical Thinking assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed

**Content**

- The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.
- Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
  * stochastic models in molecular evolution
  * phylogenetic & phylodynamic inference
  * maximum likelihood and Bayesian statistics
- Attendees will apply these concepts to a number of applications yielding biological insight into:
  * epidemiology
  * pathogen evolution
  * macroevolution of species

**Objective**

- The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

**Lecture notes**

- Lecture slides will be available on moodle.

**Literature**

- The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
  * Yang, Z. 2006. Computational Molecular Evolution.
  * Drummond, A. & Bouckaert. R. 2015. Bayesian evolutionary analysis with BEAST.

**Prerequisites / notice**

- Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course “Introduction to Programming”, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date.

For the Zurich-based students without R experience, we recommend the R course http://www.zvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d
=, or working through the script provided as part of this R course.

**Seminar in General Studies**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>252-4601-00L</td>
<td>Current Topics in Information Security</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Capkun, K. Paterson, A. Perrig, S. Shinde</td>
</tr>
</tbody>
</table>

The deadline for deregistering expires at the end of the second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.
### Abstract

The seminar covers various topics in information security: security protocols (models, specification & verification), trust management, access control, non-interference, side-channel attacks, identity-based cryptography, host-based attack detection, anomaly detection in backbone networks, key-management for sensor networks.

### Objective

The main goals of the seminar are the independent study of scientific literature and assessment of its contributions as well as learning and practicing presentation techniques.

### Content

The seminar covers various topics in information security, including network security, cryptography and security protocols. The participants are expected to read a scientific paper and present it in a 35-40 min talk. At the beginning of the semester a short introduction to presentation techniques will be given.

### Selected Topics

- security protocols: models, specification & verification
- trust management, access control and non-interference
- side-channel attacks
- identity-based cryptography
- host-based attack detection
- anomaly detection in backbone networks
- key-management for sensor networks

### Literature

The reading list will be published on the course web site.

### 252-5051-00L Advanced Topics in Machine Learning

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Semester</th>
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</thead>
<tbody>
<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning</td>
<td>2</td>
<td>2S</td>
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</tbody>
</table>

**Abstract**

In this seminar, recent papers of the pattern recognition and machine learning literature are presented and discussed. Possible topics cover statistical models in computer vision, graphical models and machine learning.

**Objective**

The seminar "Advanced Topics in Machine Learning" familiarizes students with recent developments in pattern recognition and machine learning. Original articles have to be presented and critically reviewed. The students will learn how to structure a scientific presentation in English which covers the key ideas of a scientific paper. An important goal of the seminar presentation is to summarize the essential ideas of the paper in sufficient depth while noting details which are not essential for the understanding of the work. The presentation style will play an important role and should reach the level of professional scientific presentations.

**Content**

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from computer vision or bioinformatics - two fields, which relies more and more on machine learning methodology and statistical models.

**Literature**

The papers will be presented in the first session of the seminar.

### 252-5701-00L Advanced Topics in Computer Graphics and Vision

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Semester</th>
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<tbody>
<tr>
<td>252-5701-00L</td>
<td>Advanced Topics in Computer Graphics and Vision</td>
<td>2</td>
<td>2S</td>
</tr>
</tbody>
</table>

**Abstract**

This seminar covers advanced topics in computer graphics, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each time the course is offered, a collection of research papers is selected and each student presents one paper to the class and leads a discussion about the paper and related topics.

**Objective**

The goal is to get an in-depth understanding of actual problems and research topics in the field of computer graphics as well as improve presentation skills and critical analysis skills.

**Content**

This seminar covers advanced topics in computer graphics, including both seminal research papers as well as the latest research results. Each time the course is offered, a collection of research papers is selected covering topics such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each student presents one paper to the class and leads a discussion about the paper and related topics.

**Lecture notes**

no script

**Literature**

Individual research papers are selected each term. See [http://graphics.ethz.ch/](http://graphics.ethz.ch/) for the current list.

### 263-2100-00L Research Topics in Software Engineering

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<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Semester</th>
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<tbody>
<tr>
<td>263-2100-00L</td>
<td>Research Topics in Software Engineering</td>
<td>2</td>
<td>2S</td>
</tr>
</tbody>
</table>

**Abstract**

This seminar is an opportunity to become familiar with current research in software engineering and more generally with the methods and challenges of scientific research.

**Objective**

Each student will be asked to study some papers from the recent software engineering literature and review them. This is an exercise in critical review and analysis. Active participation is required (a presentation of a paper as well as participation in discussions).

**Content**

The aim of this seminar is to introduce students to recent research results in the area of programming languages and software engineering. To accomplish that, students will study and present research papers in the area as well as participate in paper discussions. The papers will span topics in both theory and practice, including papers on program verification, program analysis, testing, programming language design, and development tools. A particular focus will be on domain-specific languages.

**Literature**

The publications to be presented will be announced on the seminar home page at least one week before the first session. Organizational note: the seminar will meet only when there is a scheduled presentation. Please consult the seminar's home page for information.

### 263-3504-00L Hardware Acceleration for Data Processing

<table>
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<th>Course Code</th>
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<th>Semester</th>
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<tr>
<td>263-3504-00L</td>
<td>Hardware Acceleration for Data Processing</td>
<td>2</td>
<td>2S</td>
</tr>
</tbody>
</table>

**Abstract**

The deadline for deregistering expires at the end of the
second week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Objective
The seminar will cover topics related to data processing using new hardware in general and hardware accelerators (GPU, FPGA, specialized processors) in particular.

Content
The general application areas are big data and machine learning. The systems covered will include systems from computer architecture, high performance computing, data appliances, and data centers.

Prerequisites / notice
Students taking this seminar should have the necessary background in systems and low level programming.

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<th>Number</th>
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<tbody>
<tr>
<td>263-3713-00L</td>
<td>Advanced Topics in Human-Centric Computer Vision</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>O. Hilliges</td>
</tr>
</tbody>
</table>

The deadline for deregistering expires at the end of the third week of the semester. Students who are still registered after that date, but do not attend the seminar, will officially fail the seminar.

Abstract
In this seminar we will discuss state-of-the-art literature on human-centric computer vision topics including but not limited to human pose estimation, hand and eye-gaze estimation as well as generative modeling of detailed human activities.

Objective
The learning objective is to analyze selected research papers published at top computer vision and machine learning venues. A key focus will be placed on identifying and discussing open problems and novel solutions in this space. The seminar will achieve this via several components: reading papers, technical presentations, writing analysis and critique summaries, class discussions, and exploration of potential research topics.

Content
The goal of the seminar is not only to familiarize students with exciting new research topics, but also to teach basic scientific writing and oral presentation skills. The seminar will have a different structure from regular seminars to encourage more discussion and a deeper learning experience.

We will treat papers as case studies and discuss them in-depth in the seminar. Once per semester, every student will have to take one of the following roles:

Presenter: Give a presentation about the paper that you read in depth.
Reviewer: Perform a critical review of the paper.
All other students: Read the paper and submit questions they have about the paper before the presentation.

Prerequisites / notice
Participation will be limited subject to available topics. Furthermore, students will have to submit a motivation paragraph. Participants will be selected based on this paragraph.

Taught competencies
- Domain B - Method-specific Competencies
- Domain C - Social Competencies
- Domain D - Personal Competencies

Literature
- (2) The Java 802 protocol emulator “JEmula802” from https://bitbucket.org/field/jemula802

Prerequisites / notice
Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required)

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<tbody>
<tr>
<td>263-0293-00L</td>
<td>Wireless Networking and Mobile Computing</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>S. Mangold</td>
</tr>
</tbody>
</table>

This course gives an overview about wireless standards and summarizes the state of art for Wi-Fi 802.11, Cellular 5G, and Internet-of-Things, including new topics such as contact tracing with Bluetooth, audio communication, cognitive radio, visible light communications. The course combines lectures with a set of assignments in which students are asked to work with a JAVA simulation tool.

Abstract
The objective of the course is to learn about the general principles of wireless communications, including physics, frequency spectrum regulation, and standards. Further, the most up-to-date standards and protocols used for wireless LAN IEEE 802.11, Wi-Fi, Internet-of-Things, sensor networks, cellular networks, visible light communication, and cognitive radios, are analyzed and evaluated. Students develop their own add-on mobile computing algorithms to improve the behavior of the systems, using a Java-based event-driven simulator. We also hand out embedded systems that can be used for experiments for optical communication.

Content
New: Starting 2020, we will address contact tracing, radio link budget, location distance measurements, and Bluetooth in more depth.

Lecture notes
The course material will be made available by the lecturer.

(1) The course webpage (look for Stefan Mangold's site)
(2) The Java 802 protocol emulator "JEmula802" from https://bitbucket.org/field/jemula802

Prerequisites / notice
Students should have interest in wireless communication, and should be familiar with Java programming. Experience with GNU Octave or Matlab will help too (not required).

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<tr>
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<tbody>
<tr>
<td>263-0600-00L</td>
<td>Research in Computer Science</td>
<td>W</td>
<td>5 credits</td>
<td>11A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Only for Computer Science MSc.

Abstract
Independent project work under the supervision of a Computer Science Professor.

Objective
Independent project work under the supervision of a Computer Science Professor.

Prerequisites / notice
Only students who fulfill one of the following requirements are allowed to begin a research project:
  a) 1 lab (interfocus course) and 1 focus course
  b) 2 core focus courses
  c) 2 labs (interfocus courses)

A task description must be submitted to the Student Administration Office at the beginning of the work.

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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
</tr>
</tbody>
</table>
The main objective of the internship is to expose students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution. They can individually choose from the entire Master course offerings from ETH Zurich, EPF Lausanne, the University of Zurich, and other Swiss universities.

### Objective

An internship provides opportunities to gain experience in an industrial environment and creates a network of contacts. The main objective of the internship is to expose students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution. To register the internship, please submit a document to the Student Administration Office containing the following information at the latest two weeks after beginning the internship:

- a detailed task description: task, technologies, milestones, etc.
- start and end date of the internship
- supervisor: name and academic degree

### Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0700-00L</td>
<td>Internship Only for Computer Science MSC.</td>
<td>W</td>
<td>0 credits</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

### Abstract

An internship provides opportunities to gain experience in an industrial environment and creates a network of contacts. The main objective of the internship is to expose students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

### Content

Internship in a computer science company, which is admitted by the CS Department at ETH. Minimum 10 weeks fulltime employment.

To register the internship, please submit a document to the Student Administration Office containing the following information at the latest two weeks after beginning the internship:

- a detailed task description: task, technologies, milestones, etc.
- start and end date of the internship
- supervisor: name and academic degree

### Lectures notes

Detailed lecture notes are available on the course web page.

### Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

### Elective Courses (only for Programme Regulations 2009)

Students can individually choose from the entire Master course offerings from ETH Zurich, EPF Lausanne, the University of Zurich and - but only with the consent of the Director of Studies - from all other Swiss universities.

For further details, refer to Art. 31 of the Regulations 2009 for the Master Program in Computer Science.

### Interfocus Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-0006-00L</td>
<td>Algorithms Lab Only for master students!</td>
<td>O</td>
<td>8 credits</td>
<td>4P+3A</td>
<td>A. Steger, E. Welzl</td>
</tr>
</tbody>
</table>

### Abstract

Students learn how to solve algorithmic problems given by a textual description (understanding problem setting, finding appropriate modeling, choosing suitable algorithms, and implementing them). Knowledge of basic algorithms and data structures is assumed; more advanced material and usage of standard libraries for combinatorial algorithms are introduced in tutorials.

### Objective

The objective of this course is to learn how to solve algorithmic problems given by a textual description. This includes appropriate problem modeling, choice of suitable (combinatorial) algorithms, and implementing them (using C/C++, STL, CGAL, and BGL).

### Literature


### Information Security Lab

Only for master students!

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-0009-00L</td>
<td>Information Security Lab Only for master students!</td>
<td>O</td>
<td>8 credits</td>
<td>2V+1U+3P+1A</td>
<td>K. Paterson, S. Capkun, D. Hofheinz, A. Perrig, S. Shinde</td>
</tr>
</tbody>
</table>

Number of participants limited to 250.
Abstract

This InterFocus Course will provide a broad, hands-on introduction to Information Security, introducing adversarial thinking and security by design as key approaches to building secure systems.

Objective

This course will introduce key concepts from Information Security, both from attack and defence perspectives. Students will gain an appreciation of the complexity and challenge of building secure systems.

Content

The course is organised in two-week segments. In each segment, a new concept from Information Security will be introduced. The overall scope will be broad, including cryptography, protocol design, network security, system security.

Lecture notes

Will be made available during the semester.

Literature

Paul C. van Oorschot, Computer Security and the Internet: Tools and Jewels.
Dan Boneh and Victor Shoup, A Graduate Course in Applied Cryptography.

Prerequisites / notice

Ideally, students will have taken the D-INFK Bachelors course "Information Security" or an equivalent course at Bachelors level.

► GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-INFK.

► Master's Thesis

Number Title Type ECTS Hours Lecturers
263-0800-00L Master's Thesis O 30 credits 64D Supervisors

Abstract

The Master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Objective

To work independently and to produce a scientifically structured work under the supervision of a Computer Science Professor.

Content

Independent project work supervised by a Computer Science professor. Duration 6 months.

Prerequisites / notice

Supervisor must be a professor at D-INFK or affiliated, see https://inf.ethz.ch/people/faculty.html

Computer Science Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A  independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D  diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R  revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

■ Special students and auditors need special permission from the lecturers.
Integrated Building Systems Master

Main Courses

Fundamental Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1633-00L</td>
<td>Energy Conversion for students outside of D-MAVT</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>I. Karlin, G. Sansavini</td>
</tr>
</tbody>
</table>

Abstract

This course is intended for students outside of D-MAVT.

Objective

Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students' intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

Content

1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

Lecture notes

Lecture slides and supplementary documentation will be available online.

Literature


Prerequisites / notice

This course is intended for students outside of D-MAVT.

Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - assessed
- Media and Digital Technologies
  - not assessed
- Problem-solving
  - assessed
- Project Management
  - not assessed

Domain C - Social Competencies
- Communication
  - not assessed
- Cooperation and Teamwork
  - not assessed
- Customer Orientation
  - not assessed
- Leadership and Responsibility
  - assessed
- Self-presentation and Social Influence
  - not assessed
- Sensitivity to Diversity
  - not assessed
- Negotiation
  - not assessed
- Integrity and Work Ethics
  - assessed
- Self-awareness and Self-reflection
  - not assessed
- Self-direction and Self-management
  - assessed

Domain D - Personal Competencies
- Adaptability and Flexibility
  - not assessed
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - assessed
- Self-awareness and Self-reflection
  - not assessed
- Self-direction and Self-management
  - assessed

Mathematics

This course gives an introduction to the following subjects:
- linear algebra (systems of linear equations, matrices, eigenvectors), calculus, multivariable calculus, differential equations.

Abstract

Basic mathematical knowledge for engineers. Mathematics as a tool to solve engineering problems.

Objective

This course gives an introduction to the following subjects:
- linear algebra (systems of linear equations, matrices, eigenvectors), calculus, multivariable calculus, differential equations.

Content

This course gives an introduction to the following subjects:
- linear algebra (systems of linear equations, matrices, eigenvectors), calculus, multivariable calculus, differential equations.

Literature

- Tom M. Apostol, Calculus, Volume 1, One-Variable Calculus with an Introduction to Linear Algebra, 2nd Edition, Wiley
- Ulrich L. Rohde, Introduction to differential calculus : Systematic studies with engineering applications for beginners, Wiley.
- Ulrich L. Rohde, Introduction to integral calculus : Systematic studies with engineering applications for beginners, Wiley.

A list will be handed out in the lecture.

Design and Building Process MIBS

ITA Pool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE

ZoomLink: https://ethz.zoom.us/j/66588100789

Abstract

"Design and Building Process MIBS" is a brief manual for prospective architects and engineers covering the competencies and the responsibilities of all involved parties through the design and building process. Lectures on twelve compact aspects gaining importance in a increasingly specialised, complex and international surrounding.
Objective

Participants will come to understand how they can best navigate the design and building process, especially in relation to understanding their profession, gaining a thorough knowledge of rules and regulations, as well as understanding how involved parties’ minds work. They will also have the opportunity to investigate ways in which they can relate to, understand, and best respond to their clients’ wants and needs. Finally, course participants will come to appreciate the various tools and instruments, which are available to them when implementing their projects. The course will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship.

Content

“Design and Building Process MIBS” is a brief manual for prospective architects and engineers covering the competencies and the responsibilities of involved parties through the design and building process. Twelve compact aspects regarding the establishment building culture are gaining importance in an increasingly specialised, complex and international surrounding. Lectures on the topics of profession, service model, organisation, project, design quality, coordination, costing, tendering and construction management, contracts and agreements, life cycle, real estate market, and getting started will guide the participants, bringing the individual pieces of knowledge into a superordinate relationship. The course introduces the key figures, depicts the criteria of the project and highlights the provided services of the consultants. In addition to discussing the basics, the terminologies and the tendencies, the lecture units will refer to the studios as well as the practice: Teaching-based case studies will compliment and deepen the understanding of the twelve selected aspects. The course is presented as a moderated seminar to allow students the opportunity for individual input: active collaboration between the students and their tutor therefore required.

Lecture notes / notice

The recordings of the lectures are available on the MAP under the link https://map.arch.ethz.ch (book symbol at the top right). Only for master students, otherwise a special permission by the lecturer is required.

Prerequisites / Literature

ITAPool - information event on the courses offered at the institute ITA: Wednesday 8th September 2021, 10-11 h, ONLINE. Assessed

103-0317-00L Introduction to Spatial Development and Transformation

Only for master students, otherwise a special permission by the lecturer is required.

Abstract

The course deals with important theoretical, material and methodical foundations for action and decision-making of spatial relevance. This course discusses central tasks and possible solutions for current and future challenges of spatial development in Switzerland and Europe.

Objective

Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

The lecture introduces necessary basic knowledge and is based on the following main topics:

- Inward development and challenges of spatial transformation
- Planning approaches and The (political) steering of spatial development
- Interplay of formal and informal processes and processes across different scales of spatial development
- Methods of action-oriented planning in situations of insecurity
- Integrated space and infrastructure development
- Different types of participation in spatial development

By taking up the lecture, the students are able to recognize cross-scale, complex tasks of spatial development and transformation and to use their theoretical, methodical and professional knowledge to clarify them.

Content

- Planning approaches and political organization in Switzerland
- Tasks of spatial relevance
- Key figures and ratios
- Drivers of spatial development
- Steering spatial development I: Policy
- Steering spatial development II: Formal and informal instruments
- Organizing spatial development I: Governance
- Organizing spatial development II: Processes and organization
- Methods in spatial planning I
- Methods in spatial planning II
- Planning in complex situations
- Participation in spatial development
- Present and future core tasks of spatial development

Lecture notes

Further information and the documents for the lecture can be found on the homepage of IRL/STL.

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0527-10L</td>
<td>Materials and Constructions</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>G. Habert, D. Sanz Pont</td>
</tr>
</tbody>
</table>

Abstract

Building materials with a special focus on regenerative materials: earth, bio-based and reuse. Sourcing, properties and performance, building envelope integration and detailing, sustainable building construction

Objective

Special focus on regenerative materials: earth, bio-based and reuse

Introduction to durability problems of building facades

Materials for the building envelope:
- Overview of structural materials and systems: concrete, wood and bamboo, earth
- Insulating materials (bio-based vs conventional)
- Air barrier, vapour barrier and sealants
- Interior finishing

Assessment of materials and components behaviour and performance

Solutions for energy retrofitting of (historical) buildings

Aspects of sustainability and durability
<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Credits</th>
<th>Type</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-8011-00L</td>
<td><strong>Building Physics: Theory and Applications</strong></td>
<td>4</td>
<td>15</td>
<td>3+1U</td>
<td>V+U</td>
<td>A. Kubilay, X. Zhou, L. D’Amato, A. Rubin, D. A. Strebek</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Objective** | The students will acquire in the following fields:  
- Indoor and outdoor climate and driving forces.  
- Hygrothermal properties of building materials.  
- Building envelope solutions and their construction.  
- Hygrothermal performance and durability. |
| **Content** | Principles of heat and mass transport, hygro-thermal performance, durability of the building envelope and interaction with indoor and outdoor climates, applications. |
| **Lecture notes** | Handouts, supporting material and exercises are provided online via Moodle. |
| 363-0389-00L | **Technology and Innovation Management**         | 3       | 15   | 2G      | G     | S. Brusoni, A. Zeijen         |
| **Abstract** | This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change. |
| **Objective** | This course intends to enable all students to:  
- understand the core concepts necessary to analyze how innovation happens  
- master the most common methods and tools organizations deploy to innovate  
- develop the ability to critically evaluate the innovation process, and act upon the main obstacles to innovation |
| **Content** | This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental decision: they have to allocate resources between well-known tasks that reliably generate positive results; or explore new ways of doing things, new technologies, products and services. The latter is a high risk choice. Its rewards can be high, but the chances of success are small. How do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, guest speakers, simulations and group work. |
| **Lecture notes** | Slides will be available on the Moodle page |
| **Literature** | Readings will be available on the Moodle page |
| **Prerequisites / notice** | The course content and methods are designed for students with some background in management and/or economics |
| 363-0503-00L | **Principles of Microeconomics**                 | 3       | 15   | 2G      | G     | M. Filippini                   |
| **Abstract** | The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution. |
| **Objective** | The learning objectives of the course are:  
(1) Students must be able to discuss basic principles, problems and approaches in microeconomics.  
(2) Students can analyse and explain simple economic principles in a market using supply and demand graphs.  
(3) Students can contrast different market structures and describe firm and consumer behaviour.  
(4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.  
(5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.  
(6) Students can apply simple mathematical concepts on economic problems. |
| **Content** | The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.  
Topics covered by the course are:  
- Supply and demand  
- Consumer demand: neoclassical and behavioural perspective  
- Cost of production: neoclassical and behavioural perspective  
- Welfare economics, deadweight losses  
- Governmental policies  
- Market failures, common resources and public goods  
- Public sector, tax system  
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)  
- International trade |
| **Lecture notes** | Lecture notes, exercises and reference material can be downloaded from Moodle. |
Literature

N. Gregory Mankiw and Mark P. Taylor (2020), "Economics", 5th edition, South-Western Cengage Learning. The book can also be used for the course 'Principles of Macroeconomics' (Sturm)

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Complementary:

GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Prerequisites / notice

Domain A - Subject-specific Competencies
Concepts and Theories
- assessed
Techniques and Technologies
- not assessed

Domain B - Method-specific Competencies
Analytical Competencies
- assessed
Decision-making
- assessed
Media and Digital Technologies
- not assessed
Problem-solving
- assessed
Project Management
- not assessed

Domain C - Social Competencies
Communication
- not assessed
Cooperation and Teamwork
- not assessed
Customer Orientation
- not assessed
Leadership and Responsibility
- not assessed
Self-presentation and Social Influence
- assessed
Sensitivity to Diversity
- not assessed
Negotiation
- not assessed

Domain D - Personal Competencies
Adaptability and Flexibility
- not assessed
Creative Thinking
- not assessed
Critical Thinking
- assessed
Integrity and Work Ethics
- not assessed
Self-awareness and Self-reflection
- assessed
Self-direction and Self-management
- not assessed

066-0423-00L Application of CFD in Buildings

Limited number of participants. Enrolment is only possible in agreement with the chair.

Abstract
Fundamentals, Applications and Project works in the area of CFD in buildings.

Objective
I- Understanding:
- Basic principles of fluid flow & heat transfer
- Basic concepts of CFD
- Validation and verification, practical guidelines

II- Application and project works of CFD in buildings. Use of the CFD software www.transat-cfd.com only, which is installed in the computer room of the Archi. Department.

Students will have two projects:

1- Group projects: Beginning of Nov. Projects will be assigned by the tutors to the students organized in groups of 2. Projects will include canonical problems in two dimensions essentially. A report is to be handed out end of Nov.

2- Individual Projects: 2nd week of Nov. to Christmas. These are individual projects, chosen by students from the list of items below.

NOTE:
Students enrolled in the "Integrated Design Project" course can use their Individual Project (this class) for their IDP project, provided (1) they attend this course (CFD in Buildings) and use the CFD code TransAT to benefit the support of the tutors.

Content
I. Fundamentals
- Basic principles of fluid flow & heat transfer
- Laminar versus turbulent flow
- Forced vs. natural convection
- Basic concepts of CFD (Discretization, schemes, solvers, etc.)
- Turbulence modelling
- Near-wall treatment
- Validation and verification, practical guidelines

II. Application of CFD for real problems including (Projects):

1. Wind – Urban Scale: students would use the building shape to determine locations for wind inlets and outlets based on façade pressures
2. Wind – Cross-ventilation: using the interior shape of a building with inlets and outlets to determine flow rates
3. Stack effect: on a windless day with people in the building, how much airflow would be anticipated airflow rate given inlets and outlets
4. Wind & heat removal: Given inlets and outlets with people in the building, how much heat is removed from the building
5. Solar chimney: given a building with a chimney, how much extra airflow is created if the chimney is solar (absorbs radiation) vs. typical (not designed to absorb radiation)
6. Plant/vegetation effects: Given a building with a courtyard, how much is cross-ventilation affected by including plants vs. not having plants or how will the plants affect stack venting.
7. Air pollution and contaminant dispersion

Lecture notes
Material (pdf files) will be sent to the students before the start of the course.
We will update the material in due time.

Use cases done in part by your colleagues in this class, from year 2015 on:

Main reference for fluid mechanics:
J.H. Spurk, Fluid Mechanics, Springer

Main reference for CFD: Ferziger and Peric, Computational Methods for Fluid Mechanics, Springer

Main Wiki reference:

Other useful papers:

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies

- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies

- Adaptability and Flexibility
- Critical Thinking


Abstract
Urban physics: wind, wind comfort, pollutant dispersion, natural ventilation, driving rain, heat islands, climate change and weather conditions, urban acoustics and energy use in the urban context.

Objective
- Basic knowledge of the global climate and the local microclimate around buildings
- Impact of urban environment on wind, ventilation, rain, pollutants, acoustics and energy, and their relation to comfort, durability, air quality and energy demand
- Application of urban physics concepts in urban design

Content
- Climate Change. The Global Picture: global energy balance, global climate models, the IPCC process. Towards regional climate scenarios: role of spatial resolution, overview of approaches, hydrostatic RCMs, cloud-resolving RCMs
- Urban micro climate and comfort: urban heat island effect, wind flow and radiation in the built environment, convective heat transport modelling, heat balance and ventilation of urban spaces - impact of morphology, outdoor wind comfort, outdoor thermal comfort
- Urban energy and urban design. Energy performance of building quarters and cities, decentralized urban energy production and storage technologies, district heating networks, optimization of energy consumption at district level, effect of the micro climate, urban heat islands, and climate change on the energy performance of buildings and building blocks.
- Wind driving rain (WDR): WDR phenomena, WDR experimental and modeling, wind blocking effect, applications and moisture durability
- Pollutant dispersion. pollutant cycle: emission, transport and deposition, air quality
- Urban acoustics. noise propagation through the urban environment, meteorological effects, urban acoustic modeling, noise reduction measures, urban vegetation

Lecture notes
The course lectures and material are provided online via Moodle.

Prerequisites / notice
For MIBS Master students 151-8011-ooL Building Phyics Theory & Application is a pre-requisite for this course or instructor permission. For others no prior knowledge is required.

066-0421-00L Building Systems I 3 credits 3G A. Schläuter, L. Baldini, I. Hischier, F. Khayatian, M. Sulzer

Abstract
Building Systems I gives an overview of fundamentals and concepts relevant for the design of building systems.

Objective
The course has the following learning objectives:
- Knowledge of the fundamentals, principles and technologies for building heating, cooling, ventilation and electricity supply
- Knowledge of the integration and interdependencies of building systems and building structure, construction and aesthetics
- Ability to estimate relevant quantities and qualities for heating/cooling/ventilation/electricity of buildings and the related supply systems
- Ability to evaluate and choose an approach for sustainable heating/cooling/ventilation/electricity, the system and its components
- Synthesis in own integrated design projects

Content
1. Comfort & Environment
2. Heating / cooling concepts and demand
3. Natural / mechanical ventilation concepts and demand
4. Solar generation / electricity storage and demand
5. Information & Communication Technologies

101-0524-00L Lean, Integrated and Digital Project Delivery 4 credits 3G D. Hall

Abstract
This course is an introduction to innovative construction project delivery through three strategies: integrated information, integrated organization, and integrated processes. Students will be introduced to project and production management concepts such as Lean Construction, Building Information Modeling, the Tri-Constraint Method, & Integrated Project Delivery.
By the end of the course, students will be able to plan and manage the lean, integrated, and digital project delivery of a construction project.

Students will know they are able to achieve this overall course goal when they can:

1. Apply the fundamental theories of lean production to the context of construction management. This includes the ability to describe the three views of production: transformation, flow and value generation; evaluate the benefits of a pull production system compared to push production systems; evaluate how production variability and uncertainty contributes to work-in-process and ‘waste’; and apply the concepts of lean production to several construction management tools including the Last Planner System, Pull Planning, Target Value Design, and Takt Planning.

2. Understand the fundamentals of Virtual Design and Construction and Building Information Modeling. This includes the ability to prepare a model breakdown structure capable of integrating project information for all stakeholders; describe the upcoming transition to a common data environment for BIM that will use platforms such as Autodesk Forge; and describe the barriers to successful implementation of BIM within construction and design firms.

3. Plan and schedule an integrated ‘5D’ scope schedule cost model using the Tri-Constraint Method. This includes the ability to understand the TCM algorithm, apply parametric logic to the creation of a virtual model for construction production; and evaluate the limitations of the critical path method when compared to resource- and space-constrained scheduling.

4. Evaluate benefits of integrated project governance compared to the organization of traditional construction project delivery systems. This includes the ability to evaluate the risks, benefits and considerations for integrated teams using multi-party relational contracts that cross disciplinary and firm boundaries; and explain to others the ‘elements’ of integrated projects (e.g. colocation, early involvement of key stakeholders, shared risk/reward, collaborative decision making).

The construction industry is continually seeking to deliver High-Performance (HP) projects for their clients. HP buildings must meet the criteria of four focus areas – buildability, operability, usability, and sustainability. The project must be buildable, as measured by metrics of cost, schedule, and quality. It must be operable, as measured by the cost of maintaining the facility for the duration of its lifecycle. It must be usable, enabling productivity, efficiency and well-being of those who will inhabit the building. Finally, it must be sustainable, minimizing the use of resources such as energy and water. Buildings that succeed in all four of these areas can be considered HP projects.

HP buildings require the integration of building systems. However, the traditional methods of planning and construction do not use an integrated approach. Project fragmentation between many stakeholders is often cited as the cause of poor project outcomes and the reason for poor productivity gains in the construction industry. In response, the construction industry has turned to new forms of integration in order to integrate the processes, organization, and information required for high performance projects.

This course investigates emerging trends in the construction industry – e.g. colocation, shared risk/reward contracts, lean construction methods, and use of shared building information models (BIM) for virtual design and construction (VDC) – as a way to achieve HP projects. For integrated projects, students will be introduced to the fundamentals of lean construction management. This course will look at the causes of variability in construction production and teach the theory of lean production for construction. Processes and technologies will be introduced for lean management, such as the last planner system, takt time planning, production tracking, and target value design.

For integrated information, students will be introduced to the fundamentals of virtual design and construction, including how to use work breakdown structures and model breakdown structures for building information modeling, and the fundamentals and opportunities for 4D scheduling, clash detection, and “5D and 6D” models. Future technologies emerging to integrate information such as the use of Autodesk Forge will be presented. Students will have the opportunity to discuss barriers in the industry to more advanced implementation of BIM and VDC.

For integrated organization, students will study the limitations of the construction industry to effectively organize for complex projects, including the challenges of managing highly independent tasks and generating knowledge and learning within large multi-organizational project teams. One emerging approach in North America known as IPD will be studied as a case example. Students will explore the benefits of certain ‘elements’ of IPD such as project team colocation, early involvement of trade contractors, shared risk/reward contracts, and collaborative decision making.

The course will also include several guest lectures from industry experts to further demonstrate how these concepts are applied in practice.

Lecture notes: Lecture Presentation slides will be available for viewing and download the day before each lecture.

The class will be presented in a "flipped classroom" environment where students will be required to do readings or watch video before class. In-class activities will act to reinforce and expand upon these primary concepts.

If possible due to COVID restrictions, students will be expected to attend a half-day workshop on the Last Planner System. The date of this workshop will be provided at a later point in time.

A full list of required readings will be made available to the students via Moodle.

Project Management for Construction Projects (101-0007-00L) is a recommended but not required prerequisite for this course.

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

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

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed

Domain D - Personal Competencies
- Negotiation: not assessed
- Critical Thinking: not assessed
- Self-direction and Self-management: not assessed

101-0608-00L Design-Integrated Life Cycle Assessment

W 3 credits 2G G. Habert

Abstract
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

Objective
The course will follow two main objectives and a third optional objective, depending on the design projects the students’ choose. At the end of the course, the students will:

1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation
Renewable Energy Technologies

Abstract
Renewable energy technologies: solar PV, solar thermal, biomass, wind, geothermal, hydro, waste-to-energy. Focus is on the engineering aspects.

Objective
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

Lecture notes
Lecture Notes containing copies of the presented slides.

Prerequisites / notice
Prerequisite: Sustainable construction (101-0577-00L). Otherwise a special permission by the lecturer is required.

Thermodynamics I, II, and III of D-MAVT.

Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

Structural Design

Abstract
The goal of the course is to introduce the civil engineering students to Structural Design, which is regarded as a discipline that relates structural behavior, construction technologies and architectural concepts. The course encourages the students to understand the relationship between the form of a structure and the forces within it by promoting the development of designed projects.

Objective
After successfully completing this course the students will be able to:
1. Critically question structural design concepts of historical and contemporary references
2. Use graphic statics and strut-and-tie models based on the Theory of Plasticity to describe the load bearing behavior of structures
3. Understand different construction technologies and have an awareness of their potential for structural design
4. Use contemporary digital tools for the design of structures in equilibrium
5. Design an appropriate structural system for a given design task taking into account architectural considerations

Content
The goal of the course is to introduce the civil engineering students to Structural Design, which is understood as a discipline that relates structural behavior, construction technologies and architectural concepts. Hence, the course encourages the students to develop an intuitive understanding of the relationship between the form of a structure and the forces within it by promoting the development of designed projects, in which the static and architectural aspects come together. The course is structured in two main parts, each developed in half of a semester: a mainly theoretical one (including the teaching of graphic statics) and a mainly applied one (focused on the development of a design project by the students using digital form-finding tools).

Theory:
Graphic statics is a graphical method developed by Prof. Karl Culmann and firstly published in 1864 at ETH Zurich. In this approach to structural analysis and design, geometric construction techniques are used to visualize the relation between the geometry of a structure and the forces acting in and on it, represented by geometrically dependent form and force diagrams.

The course will firstly review the main principles of graphic statics through a series of frontal lectures and discuss the relationship to analytical statics. Graphic statics is then used as an operative tool to design structures in equilibrium based on the lower bound theorem of the Theory of Plasticity. Additionally, the course will introduce contemporary methodologies and tools (parametric CAD software) for the interactive application of equilibrium modelling in the form of short workshops. The students will familiarize with the topic by solving exercises and confronting themselves with simple design tasks.

Design Project:
Specific structural design approaches and design methodologies based on graphic statics and references from construction history will be introduced to the students by means of seminars and workshops. By developing a design project, the students will apply these concepts and techniques in order to become proficient with open design tasks (such as the design of a bridge, a large span hall or a tower). At the end of the semester, the students present their projects to a jury of internal and external critics in a final review. The main criterion of evaluation is the students' ability to integrate architectural considerations into their structural design.

"Faustformel Tragwerksentwurf"
(Philipp Block, Christoph Gengangel, Stefan Peters, DVA Deutsche Verlags-Anstalt 2015, ISBN 978-3-421-04012-1)

"Form and Forces: Designing Efficient, Expressive Structures"

"The art of structures, Introduction to the functioning of structures in architecture"
Objective

The aims of the course are as follows:
1) To provide a thorough understanding of the basic principles of chemistry and its application.
2) To develop an understanding of the atomic and molecular nature of matter and of the chemical reactions that describe its transformations.
3) To emphasize areas considered most relevant in an engineering context.

Content

Electronic structure of atoms, chemical bonding, molecular geometry and bonding theories, intermolecular forces, gases, thermodynamics, chemical thermodynamics, chemical kinetics, equilibria, liquids and solutions, acids and bases, redox- and electrochemistry.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Lecture notes

Slides are available prior to every lecture and can be downloaded from Moodle.

Literature

The course is based on "Chemistry The Central Science" by Brown, LeMay, Bursten, Murphy, Woodward, and Stolltzuß. Pearson, 14th Edition in SI units (global edition).

Specialised Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0185-00L</td>
<td>Radiation Heat Transfer</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. Steinfeld, P. Pozivil</td>
</tr>
</tbody>
</table>

Abstract
Advanced course in radiation heat transfer

Objective
Fundamentals of radiative heat transfer and its applications. Examples are combustion and solar thermal/thermochemical processes, and other applications in the field of energy conversion and material processing.

Content

Lecture notes
Lecture Notes containing copies of the presented slides.

Literature

151-0103-00L | Fluid Dynamics II                          | W    | 3    | 2V+1U  | P. Jenny           |

Abstract

Objective
Concepts, phenomena and quantitative description of irrotational (potential), rotational, and one-dimensional compressible flows.

Content

Lecture notes
Lecture notes are available (in German).

Literature
Relevant chapters (corresponding to lecture notes) from the textbook

Prerequisites / notice
Analysis I/II, Knowledge of Fluid Dynamics I, thermodynamics of ideal gas

401-0647-00L | Introduction to Mathematical Optimization  | W    | 5    | 2V+1U  | D. Adjiaishvili    |

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering. The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.
Content
Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Literature
Information about relevant literature will be given in the lecture.

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Semester</th>
<th>Credits</th>
<th>Groups</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0477-00L</td>
<td>Acoustics I</td>
<td>Winter Semester 2021</td>
<td>6</td>
<td>4G</td>
<td>K. Heutschi</td>
</tr>
<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the Built Environment</td>
<td>Winter Semester 2021</td>
<td>3</td>
<td>2G</td>
<td>G. Habert, D. Kaushal</td>
</tr>
<tr>
<td>101-0417-00L</td>
<td>Transport Planning Methods</td>
<td>Winter Semester 2021</td>
<td>6</td>
<td>4G</td>
<td>K. W. Axhausen</td>
</tr>
</tbody>
</table>

Abstract

**227-0477-00L Acoustics I**
Introduction to the fundamentals of acoustics in the field of sound field calculations, measurement of acoustical events, outdoor sound propagation and room acoustics of large and small enclosures.

**101-0577-00L An Introduction to Sustainable Development in the Built Environment**
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change. In 2016, other political bodies made these changes more difficult to predict.

What does it mean for the built environment?
This course provides an introduction to the notion of sustainable development when applied to our built environment

Objective
At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

What is sustainable development?
In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

**101-0417-00L Transport Planning Methods**
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

Objective
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

Lecture notes

**101-0577-00L An Introduction to Sustainable Development in the Built Environment**

- Domain A - Subject-specific Competencies: Concepts and Theories (assessed)
- Domain B - Method-specific Competencies: Analytical Competencies (assessed)
- Domain C - Social Competencies: Communication (assessed)
- Domain D - Personal Competencies: Critical Thinking (assessed)

- Lecture notes: yes

- Taught competencies: Self-direction and Self-management (not assessed)

**101-0417-00L Transport Planning Methods**

- Domain A - Subject-specific Competencies: Problem-solving (assessed)
- Domain C - Social Competencies: Creative Thinking (assessed)
- Domain D - Personal Competencies: Critical Thinking (assessed)

- Lecture notes: yes

- Taught competencies: Self-direction and Self-management (assessed)
The course provides the necessary knowledge to develop models supporting the solution of given planning problems and also introduces cost-benefit analysis as a decision-making tool. Examples of such planning problems are the estimation of traffic volumes, prediction of estimated utilization of new public transport lines, and evaluation of effects (e.g. change in emissions of a city) triggered by building new infrastructure and changes to operational regulations.

To cope with that, the course is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

<table>
<thead>
<tr>
<th>101-0507-00L</th>
<th>Infrastructure Management 3: Optimisation Tools</th>
<th>W</th>
<th>6 credits</th>
<th>2G</th>
<th>B. T. Adey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course will provide an introduction to the methods and tools that can be used to determine optimal inspection and intervention strategies and work programs for infrastructure.</td>
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<tr>
<td>Objective</td>
<td>Upon successful completion of this course students will be able:</td>
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<td></td>
<td>- to use preventive maintenance models, such as block replacement, periodic preventive maintenance with minimal repair, and preventive maintenance based on parameter control, to determine when, where and what should be done to maintain infrastructure</td>
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<td></td>
<td>- to take into consideration future uncertainties in appropriate ways when devising and evaluating monitoring and management strategies for physical infrastructure</td>
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<td></td>
<td>- to use operation research methods to find optimal solutions to infrastructure management problems</td>
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<tr>
<td>Content</td>
<td>Part 1: Explanation of the principal models of preventative maintenance, including block replacement, periodic group repair, periodic maintenance with minimal repair and age replacement, and when they can be used to determine optimal intervention strategies</td>
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<td>Part 2: Explanation of preventive maintenance models that are based on parameter control, including Markovian models and opportunistic replacement models</td>
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<td>Part 3: Explanation of the methods that can be used to take into consideration the future uncertainties in the evaluation of monitoring strategies</td>
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<td>Part 4: Explanation of how operations research methods can be used to solve typical infrastructure management problems.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be given out at the beginning of the course.</td>
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<td></td>
<td>Class relevant materials will be distributed electronically before the start of class.</td>
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<tr>
<td></td>
<td>A copy of the slides will be handed out at the beginning of each class.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Successful completion of IM1: 101-0579-00 Evaluation tools is a prerequisite for this course.</td>
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</tbody>
</table>

The course explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food.

<table>
<thead>
<tr>
<th>363-0387-00L</th>
<th>Corporate Sustainability</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>V. Hoffmann, C. Benning-Bach, N. U. Blum, J. Meuer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food.</td>
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<tr>
<td>Objective</td>
<td>Students - assess the limits and the potential of corporate sustainability for sustainable development - develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method. - recognize and realize opportunities through team work for corporate sustainability in a business environment - present strategic recommendations in teams with different output formats (in-style debate, consultancy pitch, technology model walk-through, campaign video)</td>
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<tr>
<td>Content</td>
<td>In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share his insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.</td>
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<tr>
<td>Lecture notes</td>
<td><a href="http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html">http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html</a></td>
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<tr>
<td>Literature</td>
<td>Presentation slides will be made available on moodle prior to lectures.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.</td>
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</table>

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

<table>
<thead>
<tr>
<th>402-0809-01L</th>
<th>Introduction to Computational Physics (for Civil Engineers)</th>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
<th>A. Adelmann</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.</td>
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</tbody>
</table>
Objective

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes Literature

Lecture notes and slides are available online and will be distributed if desired.

Prerequisites / notice

Lecture and exercise lessons in english

402-0809-00L Introduction to Computational Physics W 8 credits 2V+2U A. Adelmann

Abstract

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include laws of motion, partial differential equations (wave equation, diffusion equation, Maxwell’s equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Objective

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes Literature

Lecture notes and slides are available online and will be distributed if desired.

Prerequisites / notice

Lecture and exercise lessons in english

101-0187-00L Structural Reliability and Risk Analysis W 3 credits 2G S. Marelli

Abstract

Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective

The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Content

Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post- and pre-post risk assessment methods are presented.

Lecture notes Literature

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Prerequisites / notice


S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

Basic course on probability theory and statistics

701-1346-00L Carbon Mitigation W 3 credits 2G N. Gruber

Abstract

Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations by guest speakers from industry and the public sector, and final presentations by the students.

Objective

The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Lecture notes Literature

None

Prerequisites / notice

Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

After this course, the students are able to understand and use the different certification labels. Building labels are used to certify buildings and neighbourhoods in term of sustainability. Many different labels have been developed and its application on 3 emblematic case study buildings will be discussed.

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

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

Principles of Macroeconomics

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

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems. This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).
Content
Three buildings case study will be presented.

Different certification schemes, including LEED (American standard), DGNB (German Standard with Swiss adaptation), Label SNBS, MINERGIE-ECO and 2000-Watt-Site (Swiss standards) will be presented and explained by experts.

After this overall general presentation and in order to have a closer look to specific aspects of sustainability, students will work in groups and assess during one or two weeks this specific criteria on one of the case studies presented before. This practical hands on the label will end with a presentation and a discussion where we will highlight differences between the labels.

This alternance of working session on one specific criteria for one specific building followed by a group presentation and discussion to compare labels is repeated for the different focus point (operation energy, mobility, daylight, indoor air quality).

Lecture notes
The slides from the presentations will be made available.

Literature
All documents for certification labels as well as detail plans of the buildings will be available for the students.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
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</thead>
<tbody>
<tr>
<td>063-0611-00L</td>
<td>The Digital in Architecture II (Exercise)</td>
<td>2</td>
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</tr>
<tr>
<td>252-0839-00L</td>
<td>Informatics</td>
<td>2</td>
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<td>L. E. Fässler, M. Dahinden</td>
</tr>
<tr>
<td>101-0007-00L</td>
<td>Project Management for Construction Projects</td>
<td>4</td>
<td>S</td>
<td>J. J. Hoffman</td>
</tr>
<tr>
<td>851-0589-00L</td>
<td>Technology and Innovation for Development</td>
<td>3</td>
<td>V</td>
<td>P. Aerni</td>
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</tbody>
</table>
Objective
- to recognize the challenges and opportunities of technological change in terms of sustainable development
- to become familiar with policy instruments to promote innovation
- to improve understanding of political decision-making processes in the regulation of science & technology
- improved understanding of the role of science and technology in the context of human and societal development

Content
Science and Technology Policy is normally associated with the improvement of national competitiveness; yet, it is also an integral part of effective environmental and development policies.

The course will discuss the challenges and opportunities of technological change in terms of sustainable development and show how public policy on the national and the international level is responding to this change.

In this context, students are to become familiar with the basic principles of political economy and New Growth Theory and how such theories help explain political decisions as well as political outcomes in the area of Science, Technology and Innovation. State interventions are either designed to regulate (e.g. environmental regulations, anti-trust law) or facilitate (e.g. intellectual property rights protection, public investment in R&D and technical education, technology transfer) technological change. This will be illustrated by looking at different industries and different national systems of innovation. Subsequently the positive and negative consequences for society and the natural environment will be discussed from a short-term and a long-term perspective.

Lecture notes
Reader with issue-specific articles. E-version is partly available under https://www.ethz.ch/content/specialinterest/gess/cis/international-relations/en/teaching/materials/tech.html

Literature

Aerni, P. 2016a. Coping with Migration-Induced Urban Growth: Addressing the Blind Spot of UN Habitat. Sustainability 8(800), doi:10.3390/su8080800


Prerequisites / notice
The 2-hour course (5-7 p.m.) will be held as a series of lectures. The course materials will be available in form of an electronic Reader at

In addition, they will have to pass a written test at the end of the course in order to obtain 3 credit points in the ECTS System. In the final mark (a) will have a weight of 40% and (b) 60%.

ETH Week 2021: Health for Tomorrow

All ETH Bachelor's, Master's and exchange students can take part in the ETH week. No prior knowledge is required

Abstract
ETH Week is an innovative one-week course designed to foster critical thinking and creative learning. Students from all departments as well as professors and external experts will work together in interdisciplinary teams. They will develop interventions that could play a role in solving some of our most pressing global challenges. In 2021, ETH Week will focus on the topic of health and well-being.
Objective
Domain specific knowledge: Students have immersed knowledge about a certain complex, societal topic which will be selected every year. They understand the complex system context of the current topic, by comprehending its scientific, technical, political, social, ecological and economic perspectives.

Analytical skills: The ETH Week participants are able to structure complex problems systematically using selected methods. They are able to acquire further knowledge and to critically analyse the knowledge in interdisciplinry groups and with experts and the help of team tutors.

Design skills: The students are able to use their knowledge and skills to develop concrete approaches for problem solving and decision making to a selected problem statement, critically reflect these approaches, assess their feasibility, to transfer them into a concrete form (physical model, prototypes, strategy paper, etc.) and to present this work in a creative way (role-plays, videos, exhibitions, etc.).

Self-competence: The students are able to plan their work effectively, efficiently and autonomously. By considering approaches from different disciplines they are able to make a judgment and form a personal opinion. In exchange with non-academic partners from business, politics, administration, nongovernmental organisations and media they are able to communicate appropriately, present their results professionally and creatively and convince a critical audience.

Social competence: The students are able to work in multidisciplinary teams, i.e. they can reflect critically their own discipline, debate with students from other disciplines and experts in a critical-constructive and respectful way and can relate their own positions to different intellectual approaches. They can assess how far they are able to actively make a contribution to society by using their personal and professional talents and skills and as "Change Agents".

Remote collaboration competence: The students work in a hybrid setting blending physical and virtual communication and collaboration methods and tools. They experience the potential and limitations of remote collaboration.

Content
The week is mainly about problem solving and design thinking applied to the complex world of health and well-being. During ETH Week students will have the opportunity to work in small interdisciplinary groups, allowing them to critically analyse both their own approaches and those of other disciplines, and to integrate these into their work.

While deepening their knowledge about health and well-being, students will be introduced to various methods and tools for generating creative ideas and understand how different people are affected by each part of the system. In addition to lectures and literature, students will acquire knowledge via excursions into the real world, empirical observations, and conversations with researchers and experts.

A key attribute of the ETH Week is that students are expected to find their own problem, rather than just solve the problem that has been handed to them.

Therefore, the first three days of the week will concentrate on identifying a problem the individual teams will work on, while the last two days are focused on generating solutions and communicating the team’s ideas.

Prerequisites / notice
No prerequisites. Programme is open to Bachelor and Masters from all ETH Departments. All students must apply through a competitive application process at www.ethz.ch/ethweek. Participation is subject to successful selection through this competitive process.

Taught competencies
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Media and Digital Technologies | assessed |
| Domain D - Personal Competencies | Problem-solving | assessed |
| Communication | assessed |
| Cooperation and Teamwork | assessed |
| Sensitivity to Diversity | assessed |
| Negotiation | assessed |
| Adaptability and Flexibility | assessed |
| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Self-direction and Self-management | assessed |

363-1065-00L Design Thinking: Human-Centred Solutions to Real World Challenges
W 5 credits 5G
S. Brusoni

Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy),
- Engage in collaborative ideation with a multidisciplinary team,
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Information and application: http://sparklabs.ch/

The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validated them through quick iterations of prototyping and testing using different tools and materials.

The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through messages beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

603-0803-01L History and Theory in Architecture IX (Avermaete) W 1 credit 1V T. Avermaete, H. Teerds

This core course (ends with <01L>) can only be passed once! Please check this before signing up.

This survey course offers an introduction to urban theory for students of architecture and urban design, by exploring the past and current discourses on cities and urban development.

It is often said that we live in an ‘urban age’: cities are the most common habitat for the inhabitants of the world, today. Moreover, while more than half of the global population lives in cities according to the reports of the UN, it is expected that within the next few decades this amount will increase to two-thirds. This ‘urban’ condition, however, cannot be generalized. Within the term ‘city’ a broad range of different urban conditions are taken together: from metropolises to suburban neighborhoods, and from shrinking (old industrial) cities to the new cities that prosper under the conditions of globalization. Nevertheless, because of the increase of the urbanized environments, the development of cities forms the topic of discussion among a wide range of people. Urban developments do concern politicians, economists, anthropologists, philosophers, citizens and activists, developers and designers. In turn, the urban realm has provoked theorists, citizens, politicians, artists and designers to think and write about its form and functioning, appearance and structure. The discourse regarding the current growth of cities has a long pedigree in history, going back to the establishment of Greek and Roman city-states. In turn, urban planners have made valuable contributions to these discussions, in writings and in actual urban design projects and proposals.

This survey course aims to offer an introduction to urban theory for students of architecture and urban design, by exploring the past and current discourses on cities and urban development. By investigating a range of topics, from politics to poverty, and from modernization to commodification, it aims to show how urban and architectural design are related to theory. The aim of the course is to challenge the question how architects and urban designers can have an influence on urban development. With this question, also students are urged to reflect upon their own position regarding architectural interventions in the urban fabric.

This course aims to offer a survey of the history and current state of urban theory for students of urban design and architecture. Weekly, one-hour lectures address one particular topic at a time (e.g. politics, public space, capital). In each lecture, this theme is investigated through three case-studies (either of particular cities or seminal contributions by theorists or designers) that highlight crucial moments in the history and developments of cities. At the same time, the case studies will be structured so as to bridge between urban theories and concrete urban situations, design reflections and political ambitions. This will help convey to students the historical pedigree of current discourses on cities, whether simultaneously gain insight the role of designers in respect to the chosen topic. Students will prepare the meetings by reading fragments from core texts on the foreground.

For this course, each week students will read fragments from key readings on the topics addressed. These readings will be made available via the website of the course.

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<thead>
<tr>
<th>Taught competencies</th>
<th>Content</th>
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<tbody>
<tr>
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<td>Concepts and Theories</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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</table>

103-0569-00L European Aspects of Spatial Development W 3 credits 2G A. Peric Momcilovic

Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making
Adaptability and Flexibility

Communication

2S

The documents for the lecture will be provided at the moodle.

Obligatory literature:


Recommended literature:

Governance models:


Planning models:


EU as a political context:


Territorial cooperation in Europe:


Planning families and cultures:


Planning systems in Europe:


Prerequisites / notice

Only for master students, otherwise a special permission by the lecturer is required.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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

Objective
The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced through a series of case studies. Students are given a theoretical background in space syntax and spatial cognition, with a view to applying this knowledge during the design process. The course covers a range of methods including visibility analysis, network analysis, conducting real-world observations, and virtual reality for architectural design. Students apply these methods to a case study of their choice, which can be at building or urban scale. For students taking a B-ARCH or M-ARCH degree, this can be a completed or ongoing design studio project. The course gives students the chance to implement the methods iteratively and explore how best to address the needs of the eventual end-user during the design process.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

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### Abstract

This course provides the basics of relational databases from the perspective of the user. We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

### Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world’s constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms”.
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn’t age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

### Content

#### Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

#### Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

#### Analytics on top of a relational database

12. Data cubes

#### Outlook

13. Outlook

### Literature

- Lecture material (slides).

### Prerequisites / notice

For non-CS/DS students only: BSc and MSc students have to show elementary knowledge of set theory and logic. Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python.

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### 252-0834-00L

#### Information Systems for Engineers

<table>
<thead>
<tr>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
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<tbody>
<tr>
<td>G. Fourny</td>
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</table>

#### Abstract

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

#### Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world’s constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms”.
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn’t age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

### Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

### Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

### Analytics on top of a relational database

12. Data cubes

### Outlook

13. Outlook

### Literature

- Lecture material (slides).

### Prerequisites / notice

For non-CS/DS students only: BSc and MSc students have to show elementary knowledge of set theory and logic. Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python.

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### 052-0707-00L

#### Urban Design III

<table>
<thead>
<tr>
<th>W</th>
<th>2 credits</th>
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<tbody>
<tr>
<td>H. Klumpner, M. Fessel</td>
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</table>
The course 'Energy- and Climate Systems III' introduces computational design and analysis methods and tools for climate responsive urban form. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasons, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how we look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.
### 151-3209-00L Engineering Design Optimization

**W 4 credits**

**K. Shea, T. Stankovic**

**Abstract**
The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them.

**Objective**
The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to apply suitable optimization methods given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and perform better optimized technical products. The exercises are MATLAB based.

**Content**
1. Optimization modeling and theory
2. Unconstrained optimization methods
3. Constrained optimization methods
4. Direct search methods
5. Stochastic and evolutionary search methods
6. Multi-objective optimization

**Lecture notes**
available on Moodle

### 101-0139-00L Scientific Machine and Deep Learning for Design and Construction in Civil Engineering

**W 3 credits**

**M. A. Kraus, D. Griego**

**Abstract**
This course will present methods of scientific machine and deep learning (ML / DL) for applications in design in civil engineering. After providing proper background on ML and the scientific ML (SciML) track, several applications of SciML together with their computational implementation during the design and construction process of the built environment are examined.

**Objective**
This course aims to provide graduate level introduction into Machine and especially scientific Machine Learning for applications in the design and construction phases of projects in civil engineering.

Upon completion of the course, the students will be able to:
1. understand main ML background theory and methods
2. make a problem and apply ML and DL in a computational framework accordingly
3. Incorporating scientific domain knowledge in the SciML process
4. Define, Plan, Conduct and Present a SciML project

**Content**
The course will include theory and algorithms for SciML, programming assignments, as well as a final project assessment.

The topics to be covered are:
1. Fundamentals of Machine and Deep Learning (ML / DL)
2. Incorporation of Domain Knowledge into ML and DL
3. ML training, validation and testing pipelines for academic and research projects

**Lecture notes**
The course script is composed by lecture slides, which are available online and will be continuously updated throughout the duration of the course.

**Literature**
A comprehensive series of computer/lab exercises and in-class demonstrations will take place, providing a "hands-on" feel for the course topics.

**Suggested Reading:**
- Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong: Mathematics for Machine Learning
- S. Guido, A. Müller: Introduction to machine learning with python. O'Reilly Media, 2016

**Prerequisites / notice**
Familiarity with MATLAB and / or Python is advised.

### 052-0639-00L Climate Responsive Architecture with Hive

**W 1 credit**

**A. Schlüter**

**Abstract**
This online course introduces a way to approach climate-responsive design using the Hive tool and how to apply it in early building design stages. Hive allows architects and building science students to understand the relation between architectural design, climate, comfort and energy. Hive is a plugin for the 3D modeling environment Rhino and its visual programming interface Grasshopper.

**Objective**
- Recall general principles of climate-responsive design and examples of it.
- Utilize 3D building geometries to conduct simplified energy demand and supply simulations.
- Observe relevant physical principles and interactions between climate, energy and geometry.
- Implement passive and active concepts for Climate Responsive Design.
- Apply Hive for building design analysis and integrate it into own designs or in design courses.
- Identify and harness synergies and trade-offs between climate, energy and architectural design aspects.

**Content**
The course can be frequented individually, or as a prerequisite for other courses such as the master course Climate and Energy Systems 3 or architectural design studios.

**Modules:**
1. Course overview.
2. Introduction to climate-responsive design.
3. Introduction to Rhino, Grasshopper and Hive.
4. Early solar analyses.
7. Real-world Applications and Examples.

**Prerequisites / notice**
A working Rhino 6 or 7 license is necessary.

### 851-0096-00L Science in Society

**W 3 credits**

**L. Wingert**

**Abstract**
Whose voice should count how much? On the authority of the sciences in democracy.

**Objective**
Not a few members of the elites argue that important issues in democracy like policies against climate change, free trade agreements, urban planning are too complex for the people. Experts should have a stronger say in politics. Less democracy = more rationality? The course should give an answer to this question.
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications, regarding products & services as well as organisations.

In particular, students completing the course should have the
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management

Content
Part I (Advanced Environmental Assessments)
- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multinput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

Part II (Implementation of Environmental and other Sustainability Goals):
- Sustainability problems of the current economic system and its measuring units;
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication;
- Sustainability Opportunities and Innovation
- The concept of ‘Continuous Improvement’
- Life Cycle Costing, Life Cycle Management
- environmental performance measurement of an organisation, including ‘organisational LCA’ (Ecobalance), based on practical examples of companies and new concepts
- single score env. assessment methods (Swiss ecopoints)
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Students will get small excercises related to course issues.

Lecture notes
Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on Ilias

Literature
Will be made available.

Prerequisites / notice
This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5,2)).

Project Courses

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>066-0425-00L</td>
<td>Integrated Design MIBS</td>
<td>W</td>
<td>6</td>
<td>3+3U</td>
<td>A. Schlüter</td>
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</tbody>
</table>

Abstract
During the integrated design studio students work on a selected integrated architectural / urban design project, considering both energy- and climate systems (HVAC) as well architectural and urban design in a specific site context. The objective is to follow an integrated design process to achieve synergistic solutions.

Objective
The integrated design studio enables students to identify site specific energy demand and potentials, develop integrated energy and climate systems on both the urban and building scale and evaluate their interactions and impact on building design and operation.

Content
During the studio students will work in groups on a contemporary integrated design project (urban and / or building scale) executing an integrated design process from the analysis of site potentials, the identification of demands, the development of an urban scale energy concept and a matching building energy- and HVAC-systems concept. Input lectures from academics and professionals will highlight specific topics relevant to the task. The projects will be presented by the student groups and discussed with internal and external reviewers at midterm and at the final presentations.

Lecture notes
Scripts are specific to the design task and distributed at the beginning of the course.

Literature
A literature list will be distributed at the beginning of the course.

Prerequisites / notice
Students must have successfully passed the first year of MIBS studies.

Semester Project
### GESS Science in Perspective

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>052-0801-00L</td>
<td>Global History of Urban Design I</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>T. Avermaete</td>
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</table>

**Abstract**
The course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

**Objective**
The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students’ future design work.

**Content**
In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

- 01. The History and Theory of the City as Project
- 02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
- 03: The Idea of the Polis: Rome, Greece and Beyond
- 04: The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
- 05: Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
- 06: Of Absolutism and Enlightenment: Baroque, Defense and Colonization
- 07: The City of Labor; Company Towns as Cross-Cultural Phenomenon
- 09: Gardens Cities of Tomorrow: From the Global North to the Global South and Back Again
- 010: Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
- 11: The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

**Lecture notes**
Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

**Literature**
There are three books that will function as main reference literature throughout the course:


These books are reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

**Prerequisites / notice**
A list of further recommended literature will be found within each chapter of the readier (Skript).

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### Other Courses

#### Open- and User Innovation

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0609-06L</td>
<td>Governing the Energy Transition</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>T. Schmidt, N. Schmid, S. Sewerin</td>
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</table>

**Abstract**
This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socio-economic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.

**Objective**
- To gain an overview of the history of the transition of large technical systems
- To recognize current challenges in the energy system to understand the theoretical frameworks and concepts for studying transitions
- To gain knowledge on the role of policy and politics in energy transitions

**Content**
Climate change, access to energy and other societal challenges are directly linked to the way we use and create energy. Both the 2015 United Nations Paris climate change agreement and the UN Sustainable Development Goals make a fast and extensive transition of the energy system necessary.

This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical framworks and concepts for studying innovation and transitions. It then focuses on the role of policy and policy change in governing the energy transition, considering the role of political actors, institutions and policy feedback.

The grade will be determined by a final exam.

**Lecture notes**
Slides and reading material will be made available via moodle.ethz.ch (only for registered students).

**Prerequisites / notice**
This course is particularly suited for students of the following programmes: MA Comparative International Studies; MSc Energy Science & Technology; MSc Environmental Sciences; MSc Management, Technology & Economics; MSc Science, Technology & Policy; ETH & UZH PhD programmes.

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### Abstract
The course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.

### Objective
The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management and develop strategies to harness the value of user-developed ideas and contributions for firms and other organizations.

The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active lass participation is required.

### Content
This course on user innovation extends courses on knowledge management and innovation as well as marketing. The students are introduced to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies. Theoretical underpinnings taught in the course include models of innovation, the structuration of technology, and an introduction to entrepreneurship.

The slides of the lectures are made available and updated continuously through the SMI website:

### Literature
Relevant literature for the exam includes the slides and the reading assignments. The corresponding papers are either available from the author online or distributed during class.

Reading assignments: please consult the SMI website:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Lecture</th>
<th>T. Bernauer</th>
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<tbody>
<tr>
<td>860-0023-00L</td>
<td>International Environmental Politics</td>
<td>3</td>
<td>W</td>
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<td></td>
<td>Particularly suitable for students of D-ITET, D-USYS</td>
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<td>Abstract</td>
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<td></td>
<td>This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.</td>
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<td>The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.</td>
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<td>Content</td>
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<td>This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.</td>
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<td>The course is open to all ETH students. Participation does not require previous coursework in the social sciences.</td>
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<td>After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).</td>
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<td>Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.</td>
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<td>2. Reading assignments, available via Moodle, for a few selected course units</td>
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<td>3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).</td>
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Objective
- Students get a broad understanding of some of the most important issues and discussions related to sustainable development.
- Students get exposed to diverse realities of young people in developing countries.
- Students can critically reflect upon the information that is presented to them in the movies and relate it to the broader discussions around sustainable development.
- Students reflect on issues concerning communicating research and the realities of low-income settings to a wider public.

Content
The aim of the course is to deepen student’s knowledge about global issues and to inspire them to reflect critically upon complex topics, which are related to the broader discourse on sustainable development. In each class, we show a documentary film, which is linked to one of the five critical areas of the 2030 Agenda (Planet, People, Prosperity, Peace and Partnerships), putting specific focus on realities in developing countries. Following the movie screenings, we will discuss the topic of the film in the light of sustainable development with an expert from academia and/or a practitioner from the field of development cooperation. In preparation for each class, the students read an academic paper, which will also be considered in the discussion. The idea of “Bridging Art and Science” is to expose an interdisciplinary group of students to artistic and scientific perspectives alike and to challenge them to deal with bias and polarization, and the role that the media and films play in that regard. The participants of the course will be given the chance to embrace the complexity of sustainable global development.

851-0252-01L Human-Computer Interaction: Cognition and Usability

Number of participants limited to 35.

Abstract
This seminar introduces theory and methods in human-computer interaction and usability. Cognitive Science provides a theoretical framework for designing user interfaces as well as a range of methods for assessing usability (user testing, cognitive walkthrough, GOMS). The seminar will provide an opportunity to experience some of the methods in applied group projects.

Objective
This seminar will introduce key topics, theories and methodology in human-computer interaction (HCI) and usability. Presentations will cover basics of human-computer interaction and selected topics like mobile interaction, adaptive systems, human error and attention. A focus of the seminar will be on getting to know evaluation techniques in HCI. Students form work groups that first familiarize themselves with a select usability evaluation method (e.g., user testing, GOMS, task analysis, heuristic evaluation, questionnaires or Cognitive Walkthrough). They will then apply the methods to a human-computer interaction setting (e.g. an existing software or hardware interface) and present the method as well as their procedure and results to the plenary. Active participation is vital for the success of the seminar, and students are expected to contribute to presentations of foundational themes, methods and results of their chosen group project. In order to obtain course credit a written essay / report will be required (details to be specified in the introductory session of the course).

851-0311-00L Psychological Aspects of Risk Management and Technology

Number of participants limited to 65.

Abstract
Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are treated. Three components of risk management (risk identification/evaluation, risk mitigation, risk communication) and underlying psychological and organizational processes are discussed, using company case studies to promote in-depth understanding.

Objective
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about and (partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:
A) Attendance of lectures that provide the theoretical foundations of "Psychological Aspects of Risk Management and Technology" together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication
- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty
- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)
- Group projects related to company case studies

There is no script, but slides will be made available before the lectures.

There are texts for each of the course topics made available before the lectures.

The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

851-0742-00L Contract Design I

This course is taught by Professor Alexander Stremitzer (https://laweconbusiness.ethz.ch/group/professor/stremitzer). Note that this is NOT a legal drafting class that focuses on contractual language. Instead, in Contract Design I, you will learn what the content of a contract should be so that parties can reach their goals.
You can find all course materials and the most recent announcements on Moodle. Please log in to Moodle using your ETH or UZH credentials. Then search for “Contract Design I (851-0742-00L; Fall 2021)” and enroll. The password is “ContractDesign01”.

Number of participants limited to 160.

Max 80 ETHZ and 80 UZH Students

Abstract
Contract Design I aims to bridge the gap between economic contract theory, contract law, and the writing of real-world contracts. In this course, we take a systematic approach to contract design. This means we first analyze the economic environment in which a transaction takes place, and then engineer contracts that achieve the desired outcome.

Objective
Contracts are agreements between parties to engage in transactions. A good contract creates value by giving parties the right incentives to meet their objectives. A good contract designer scrutinizes the economic situation in which parties find themselves and tailors the contract to the challenges at hand. To help you become sophisticated contract designers, we draw from insights, for which more than half a dozen Nobel Prizes were awarded in the past two decades, and transfer them to the art of writing real-world contracts. In other words, Contract Design I will provide you with analytical tools related to contracting that are invaluable to successful lawyers, business leaders, and startup founders.

In Contract Design I, you will be asked to watch a series of videos (10-15 minutes each) that we produced for this course. These video episodes introduce you to key concepts of economic, behavioral, and experimental contract theory. We will cover topics such as moral hazard, adverse selection, elicitation mechanisms, relationship-specific investments, and relational contracting. You can find the welcome video at this link (https://www.youtube.com/watch?v=CvIdfC70zQ8). However, this course prioritizes applications of contract design. Therefore, we will use class time to discuss a selection of exciting real-world case studies, ranging from purchases & sales of assets, oil & gas exploration, movie production & distribution, construction & development, M&A deals, to executive compensation and many other types of transactions.

ETH students: Your final grade will consist of two components: 1) You are required to take weekly computer-based quizzes during class time. Thus, it is imperative that you attend the lectures to be able to finish the quizzes and pass this course. Moreover, we regularly post questions regarding the case studies that we examine in class. 2) You have to compose short responses to these questions and upload them. Note that UZH students enrolling in this course earn more ECTS on completing this course than ETH students. Therefore, ETH students must hand in an extensive group project in addition to the weekly quizzes and short responses.

Lecture notes
Handouts, prerecorded videos, slides, and other materials

Prerequisites / notice
Contract Design I is available to ETH students through the Science in Perspective (SiP) Program of D-GESS. This course is particularly suitable for students of D-ARCH, D-BAUG, D-CHAB, D-MATH, D-MTEC, D-INFK, and D-MAVT. If you have any questions on Contract Design I, please send an e-mail to Professor Stremitzer’s Teaching Assistant Diego Caldera (diegoalberto.calderaherrera@uzh.ch).

851-0252-15L Network Analysis 3 credits 2V U. Brandes

Abstract
Particularly suitable for students of D-INFK, D-MATH

Network science is a distinct domain of data science that is characterized by a specific kind of data being studied. While areas of application range from archaeology to zoology, we concern ourselves with social networks for the most part. Emphasis is placed on descriptive and analytic approaches rather than theorizing, modeling, or data collection.

Objective
Students will be able to identify and categorize research problems that call for network approaches while appreciating differences across application domains and contexts. They will master a suite of mathematical and computational tools, and know how to design or adapt suitable methods for analysis.

In particular, they will be able to evaluate such methods in terms of appropriateness and efficiency.

Content
The following topics will be covered with an emphasis on structural and computational approaches and frequent reference to their suitability with respect to substantive theory:

- Empirical Research and Network Data
- Macro and Micro Structure
- Centrality
- Roles
- Cohesion

Lecture notes
Lecture notes are distributed via the associated course moodle.

Literature


and Games 4

Number of participants limited to 100.

Prerequisites: Basic programming skills, elementary probability and statistics.

Abstract
This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research. Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.

Objective
The students are expected to know a programming language and environment (Python, Java or Matlab) as a tool to solve various scientific problems. The use of a high-level programming environment makes it possible to quickly find numerical solutions to a wide range of scientific problems. Students will learn to take advantage of a rich set of tools to present their results numerically and graphically.

The students should be able to implement simulation models and document their skills through a seminar thesis and finally give a short oral presentation.

Content
Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.

Lecture notes
The lecture slides will be presented on the course web page after each lecture.
**Literature**

Agent-Based Modeling  
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization  

Traffic and related self-driven many-particle systems  
Reviews of Modern Physics 73, 1067  
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)  
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics  

Further literature will be recommended in the lectures.

**Prerequisites / notice**

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>assessed</td>
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<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td>Negotiation</td>
<td>not assessed</td>
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</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tr>
</tbody>
</table>

**851-0467-00L From Traffic Modeling to Smart Cities and Digital Democracies**  
*Number of participants limited to 50.*

**Abstract**

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will reflect on the question of how democracy could be digitally upgraded to promote innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

**Objective**

To collect credit points, students will have to give a 30-40 minute presentation in the seminar, after which the presentation will be discussed. The presentation will be graded.

**Content**

This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.
Literature

Martin Treiber and Arne Kesting
Traffic Flow Dynamics: Data, Models and Simulation

Dirk Helbing
Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

Dirk Helbing
An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Michael Batty, Kay Axhausen et al.
Smart cities of the future
Books by Michael Batty
https://link.springer.com/article/10.1140/epjst/e2012-01703-3

How social influence can undermine the wisdom of crowd effect
https://www.pnas.org/content/108/22/2020

Evidence for a collective intelligence factor in the performance of human groups
https://science.sciencemag.org/content/330/6004/686.full

Optimal incentives for collective intelligence
https://www.pnas.org/content/114/20/5077.short

Collective Intelligence: Creating a Prosperous World at Peace
https://www.amazon.com/Collective-Intelligence-Creating-Prosperous-World/dp/097156616X/

Big Mind: How Collective Intelligence Can Change Our World
https://www.amazon.com/Big-Mind-Collective-Intelligence-Change/dp/0691170797/

Programming Collective Intelligence
https://www.amazon.com/Programming-Collective-Intelligence-Building-Applications/dp/0596529325/

Urban architecture as connective-collective intelligence. Which spaces of interaction?
https://www.mdpi.com/2071-1050/5/7/2928

Build digital democracy
https://www.nature.com/news/society-build-digital-democracy-1.18690

How to make democracy work in the digital age
http://www.huffingtonpost.com/entry/how-to-make-democracy-work-in-the-digital-age_us_57a2f488e4b0456cb7e17e0f

Digital Democracy: How to make it work?
http://futurict.blogspot.com/2020/06/digital-democracy-how-to-make-it-work.html

Proof of witness presence: Blockchain consensus for augmented democracy in smart cities

Iterative Learning Control for Multi-agent Systems Coordination
https://www.amazon.co.uk/Iterative-Learning-Control-Multi-agent-Coordination-ebook/dp/B06XJVQC41/ref=sr_1_fkmr1_1?dchild=1&amp;keywords=coordination+Jennings+multi-agent&amp;qid=1601973480&amp;sr=8-1-fkmr1

Decentralized Collective Learning for Self-managed Sharing Economies
https://dl.acm.org/doi/abs/10.1145/3277668

Further literature will be recommended in the lectures.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories (assessed)
- Techniques and Technologies (assessed)

Domain B - Method-specific Competencies
- Analytical Competencies (assessed)
- Decision-making (not assessed)
- Media and Digital Technologies (assessed)
- Problem-solving (assessed)
- Project Management (not assessed)

Domain C - Social Competencies
- Communication (assessed)
- Cooperation and Teamwork (not assessed)
- Customer Orientation (not assessed)
- Leadership and Responsibility (not assessed)
- Self-presentation and Social Influence (not assessed)
- Sensitivity to Diversity (not assessed)
- Negotiation (not assessed)

Domain D - Personal Competencies
- Adaptability and Flexibility (not assessed)
- Creative Thinking (assessed)
- Critical Thinking (assessed)
- Integrity and Work Ethics (assessed)
- Self-awareness and Self-reflection (assessed)
- Self-direction and Self-management (assessed)

Master's Thesis

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

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

Master thesis are supervised and reviewed by one or several professors and possibly by other persons at the same time. At least one professor has to be a member of a department involved in the study programme (article 2). This regulation is also valid for master thesis taking place outside ETH Zurich.

Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>066-0434-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>40D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract

A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking.

Objective

A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking.

Content

A 6-months Master thesis completes the Master's program of Integrated Building Systems. With the thesis project students are expected to demonstrate their ability to independent and structured scientific thinking. The thesis can be performed either at ETH Zurich, an industrial enterprise, or in a research institution, but has to be advised by one or more professors affiliated with the Master program "Integrated building systems".

The responsible supervisor defines the topic in consultation with the student, together with the scope of work, criteria of assessment, and dates of beginning and delivery of the work.

Course Units for Additional Admission Requirements

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0414-AAL</td>
<td>Transport Planning (Transportation I)</td>
<td>E-</td>
<td>3 credits</td>
<td>6R</td>
<td>K. W. Axhausen</td>
</tr>
</tbody>
</table>

Abstract

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

Objective

The course introduces the basic theories and methods of transport planning.

Content

Basic theoretical links between transport, space and economic development; basic terminology; measurement and observation of travel behaviour; methods of the four stage approach; cost-benefit analysis.

Literature

### Key for Hours

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

**ECTS**

- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Interdisciplinary Sciences Bachelor

► Physical-Chemical Direction

►► 1. Semester (Physical-Chemical Direction)

►►► Compulsory Subjects First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10</td>
<td>6V+3U</td>
<td>M. Einsiedler</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.

**Objective**

The ability to work with the basics of calculus in a mathematically rigorous way.

**Literature**

H. Amann, J. Escher: Analysis I
https://link.springer.com/book/10.1007/978-3-7643-7756-4

J. Appell: Analysis in Beispielen und Gegenbeispielen

R. Courant: Vorlesungen über Differential- und Integralrechnung

O. Forster: Analysis 1

H. Heuser: Lehrbuch der Analysis

K. Königsberger: Analysis 1
https://link.springer.com/book/10.1007/978-3-642-18490-1

W. Walter: Analysis 1
https://link.springer.com/book/10.1007/978-3-540-35078-0

V. Zorich: Mathematical Analysis I (englisch)

A. Beutelspacher: "Das ist o.B.d.A. trivial"

H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten

| 401-1151-00L| Linear Algebra I                           | O    | 7    | 4V+2U   | R. Pink            |

**Abstract**


**Objective**

- Mastering basic concepts of Linear Algebra
- Introduction to mathematical methods

**Content**

- Basics
- Vectorspaces and linear maps
- Systems of linear equations and matrices
- Determinants
- Endomorphisms and eigenvalues

**Literature**

We publish a summary of the content of the lecture course on the homepage: http://metaphor.ethz.ch/x/2021/hs/401-1151-00L/

Besides this we recommend one textbook about Linear Algebra, for instance one of these:

  https://www.degruyter.com/search?query=kowalsky+michler

In addition we recommend this general introduction into studying mathematics:

- H. Schichl and R. Steinbauer: Einführung in das mathematische Arbeiten. Springer-Verlag 2012. Link:

| 402-1701-00L| Physics I                                   | O    | 7    | 4V+2U   | K. Ensslin         |

**Abstract**

This course gives a first introduction to Physics with an emphasis on classical mechanics.

**Objective**

Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.

| 529-0011-01L| General Chemistry (Physical Chemistry) I   | O    | 3    | 2V+1U   | H. J. Wörner       |

**Abstract**

Die Vorlesung vermittelt eine Einführung in einige physikalischen Grundlagen der Chemie, insbesondere in die Radioaktivität, die Quantenmechanik, den Aufbau der Materie und eines Atoms, des Periodensystems der Elemente und die chemische Bindung.
Objective
Die Studierenden sind nach der Vorlesung in der Lage,
- für die Chemie wichtigen physikalischen Grössen und deren Einheiten zu rechnen,
- einige Eigenschaften chemisch relevanter Teilchen zu benennen und experimentelle Methoden zur Bestimmung dieser Eigenschaften vorzuschlagen,
- Anwendungen und Gefahren der Radioaktivität zu benennen, radioaktive Zerfallsprozesse zu kategorisieren und den zeitlichen Verlauf von einfachen Zerfallsreaktionen mathematisch wiedergeben sowohl qualitativ vorherzusagen und darzustellen,
- Wellen- und Teilchen eigenschaften von elektromagnetischer Strahlung und Materie zu beschreiben und experimentelle Methoden zu deren Nachweis vorzuschlagen,
- die Grundlagen der Quantenmechanik (Bedeutung der Wellenfunktion, Heisenbergsche Unschärferelation, Operatoren, Kommutatoren) zu erklären und einfache Rechnungen damit auszuführen,
- Absorptions- und Emissionspektren von Elektronenatomen zu analysieren und zu berechnen,
- die Schrödingergleichung für ein molekulares Molekülsystemen aufzustellen,
- die Schrödingerformel für die Modellsysteme Teilchen im Kasten und harmonischer Oszillator in einer Dimension selbstständig zu lösen und auf höherdimensionale nicht-wechselwirkende Probleme zu verallgemeinern,
- Molekülschwingungen von zweiatomigen Molekülen mit dem Modell des harmonischen und des anharmonischen Oszillators zu modellieren,
- das Konzept eines Orbitals zu erklären und die qualitative Form der Orbitale des Wasserstoffatoms mathematisch und bildlich wiederzugeben,
- den Aufbau des Periodensystems der Elemente mit Hilfe des Orbitalkonzepts zu erklären,
- Ähnlichkeiten in der elektronischen Struktur von Atomen zu erkennen und zu benutzen, um chemisch relevante Eigenschaften vorzusagen, und
- Termsymbole für atomare Grundzustände aufzustellen.

Content
Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic orbitals and energy levels: ionization energies, atomic spectroscopy, term values and symbols. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals.

Lecture notes
See homepage of the lecture.

Literature
See homepage of the lecture.

Prerequisites / notice
Voraussetzungen: Maturastoff. Insbesondere Integral- und Differentialrechnung;

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed

Additional First Year Compulsory Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0011-04L</td>
<td>Practical Course General Chemistry ■</td>
<td>O</td>
<td>8 credits</td>
<td>12P</td>
<td>H. V. Schönberg, E. C. Meister</td>
</tr>
</tbody>
</table>

Abstract
Qualitative analysis (determination of cations and anions), acid-base-equilibria (pH-values, titrations, buffer), precipitation equilibria (gravimetry, potentiometry, conductivity), redox reactions (syntheses, redox-titrations, galvanic elements), metal complexes (syntheses, complexometric titration).

Analysis of measured data, vapour pressure, conductivity, colorimetry, solubility.

Objective
Qualitative analysis (simple cation and anion separation process, determination of cations and anions), acid-base-equilibria (strengths of acids and bases, pH- and pKa-values, titrations, buffer systems, Kjeldahl determination), precipitation equilibria (gravimetry, potentiometry, conductivity), oxidation state and redox behaviour (syntheses), redox-titrations, galvanic elements, metal complexes (syntheses of complexes, ligand exchange reactions, complexometric titration).

Analysis of measured values (measuring error, average value, error analysis), states of aggregation (vapour pressure), characteristics of electrolytes (conductivity measurements), thermodynamics (calorimetry, solubility).

Content
The general aim for the students of the practical course in general chemistry is an introduction in the scientific work and to get familiar with simple experimental procedures in a chemical laboratory. In general, first experiences with the principal reaction behaviour of a variety of different substances will be made. The chemical characteristics of these will be elucidated by a series of quantitative experiments alongside with the corresponding qualitative analyses. In order to get an overview of classes of substances as well as some general phenomena in chemistry suitable experiments have been chosen. In the second part of the practical course, i.e. physical chemistry, the behaviour of substances in their states of aggregation as well as changes of selected physical values will be recorded and discussed.

Lecture notes
http://www.gruetzmacher.ethz.ch/education/labcourses

Literature
Moodle Lernplattform

Compulsory: online enrolment latest one week after start of the semester

Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0011-02L</td>
<td>General Chemistry (Inorganic Chemistry) I</td>
<td>W+</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Togni</td>
</tr>
</tbody>
</table>

Abstract
Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions.

Objective
Understanding and describing ionic equilibria from both a qualitative and a quantitative perspective.

Content
Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvanic cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility.

Lecture notes
Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.

Literature

General Chemistry (Organic Chemistry) I  W+  3 credits  2V+1U  P. Chen

Abstract
Introduction to Organic Chemistry. Classical structure theory, stereochemistry, chemical bonds and bonding, symmetry, nomenclature, organic thermochemistry, conformational analysis, basics of chemical reactions.

Objective
Introduction to the structures of organic compounds as well as the structural and energetic basis of organic chemistry.
Introduction to the history of organic chemistry, introduction to nomenclature, learning of classical structures and stereochemistry: isomerism, Fischer projections, CIP rules, point groups, molecular symmetry and chirality, toxicity, chemical bonding: Lewis bonding model and resonance theory in organic chemistry, description of linear and cyclic conjugated molecules, aromaticity, Huckel rules, organic thermochemistry, learning of organic chemistry reactions, intermolecular interactions.

Lecture notes

Unterlagen werden als PDF über die ILIAS-Plattform zur Verfügung gestellt

Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson and Rutherford

Concepts and Theories

A basic introduction to quantum and atomic physics, including basics of optics and equilibrium statistical physics. The course will focus on the relation of these topics to experimental methods and observations.

Prerequisites / notice

Voraussetzungen:
- Mathematik I und II
- Allgemeine Chemie I und II
- Physikalische Chemie I

Literature


Learning objectives

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0422-00L</td>
<td>Physical Chemistry II: Chemical Reaction</td>
<td>O</td>
<td>4</td>
<td>3V+1U</td>
<td>F. Merkt, U. Hollenstein</td>
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<tr>
<td></td>
<td>Kinetics</td>
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<tr>
<td></td>
<td>Introduction to Chemical Reaction Kinetics</td>
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<td>Fundamental concepts: rate laws, elementary</td>
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<td>reactions and composite reactions, molecular</td>
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<td>reaction order. Experimental methods in reaction</td>
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<tr>
<td>402-2883-00L</td>
<td>Physics III</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>U. Keller</td>
</tr>
<tr>
<td></td>
<td>Introductory course on quantum and atomic</td>
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<td>physics including optics and statistical physics.</td>
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<td></td>
<td>Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford</td>
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<tr>
<td></td>
<td>Streuung, Compton Streuung, Bohrsche Atommolde, de-Brogie Materiewellen.</td>
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<td></td>
<td>Optik-Wellenoptik; Linsen, Abbildungssysteme, Brechung und Fermatsches Prinzip, Beugung, Interferenz, Fabry-Perot, Interferometer, Spektrometer.</td>
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<td>Quantenmechanik: Dualismus Teilchen-Welle, Wellenfunktionen, Operatoren, Schrödinger-Gleichung, Potentialstufe und Potentialkasten, harmonischer Oszillator</td>
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<td></td>
<td>Statistische Physik: Wahrscheinlichkeitsverteilungen, Ideales Gas, Äquivaltionsgesetz, Zustandsdichte, Maxwell-Boltzmann-Verteilung, Fermi-Dirac-Statistik für Fermionen, Bose-Einstein-Statistik für Bosonen, Elektronengas, Herleitung Planck'sche Strahlungsgesetz (Photozengas)</td>
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<td></td>
<td>Lecture notes</td>
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<td></td>
<td>Literature</td>
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<tr>
<td></td>
<td>M. Alonso, E. J. Finn</td>
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<td></td>
<td>Quantenphysik und Statistische Physik</td>
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<td></td>
<td>R. Oldenburg Verlag, München</td>
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<td>5. Auflage</td>
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<td>ISBN 978-3-486-71310-4</td>
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3. Semester (Physical-Chemical Direction)

4V+2U

Introduction to Chemical Reaction Kinetics


Literature

- Physikalische Chemie I
- Allgemeine Chemie I und II
- Physikalische Chemie I

Electives

Autumn Semester 2021
The Bachelor’s programme in Interdisciplinary Sciences allows students to choose from any subject taught at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the 2nd year. See the Programme Regulations 2018 for further details.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0847-00L</td>
<td>Computer Science</td>
<td>W</td>
<td>5</td>
<td>2V+2U</td>
<td>R. Sasse, F. O. Friedrich Wicker</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.</td>
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<tr>
<td>Objective</td>
<td>Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens &quot;behind the scenes&quot; when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.</td>
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<tr>
<td>Content</td>
<td>The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.</td>
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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2303-00L</td>
<td>Complex Analysis</td>
<td>W</td>
<td>6</td>
<td>3V+2U</td>
<td>T. H. Willwacher</td>
</tr>
<tr>
<td>Abstract</td>
<td>Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, special functions, conformal mappings, Riemann mapping theorem.</td>
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<tr>
<td>Objective</td>
<td>Working knowledge of functions of one complex variables; in particular applications of the residue theorem.</td>
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<tr>
<td>Lecture notes</td>
<td>English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2333-00L</td>
<td>Methods of Mathematical Physics I</td>
<td>W</td>
<td>6</td>
<td>3V+2U</td>
<td>G. Felder</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0205-00L</td>
<td>Quantum Mechanics I</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>M. Gaberdiel</td>
</tr>
<tr>
<td>Objective</td>
<td>Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.</td>
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<tr>
<td>Content</td>
<td>The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.</td>
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<tr>
<td>Lecture notes</td>
<td>Auf Moodle, in deutscher Sprache</td>
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</tr>
</tbody>
</table>
Introduction to Solid State Physics

C. Degen

2V+1U

Semiconductor Nanostructures

T. M. Ihn

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. Electron in a magnetic field, Shubnikov-de Haas effect
2. Conductance quantization in quantum point contacts
3. Interference effects in Aharonov-Bohm rings
4. Coulomb blockade and quantum dots

The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, magnetism, superconductivity.

In addition to the lecture notes, the following supplementary books can be recommended:


In the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. Electron in a magnetic field, Shubnikov-de Haas effect
2. Conductance quantization in quantum point contacts
3. Interference effects in Aharonov-Bohm rings
4. Coulomb blockade and quantum dots

The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, thermal properties of insulators; metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism, superconductivity.

The script will be available on moodle.

Prerequisites / notice

Voraussetzungen: Physik I, II, III wünschenswert

402-0263-00L

Astrophysics I

S. Lilly

W 10 credits 3V+2U

Abstract

This introductory course will develop basic concepts in astrophysics as applied to the understanding of the physics of planets, stars, galaxies, and the Universe.

Objective

The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

Content

1. Introduction and overview
2. Stellar crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes


In addition to the lecture notes, the following supplementary books can be recommended:


Prerequisites / notice

The course is taught in English.

Very ambitioned students in the third year may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.

Voraussetzungen: Physik I, II, III wünschenswert

Prerequisites / notice

Voraussetzungen: Physik I, II, III wünschenswert

402-0595-00L

Semiconductor Nanostructures

T. M. Ihn

W 6 credits 2V+1U

Abstract

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. The Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

Content

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes


In addition to the lecture notes, the following supplementary books can be recommended:


Prerequisites / notice

The course is taught in English.

Very ambitioned students in the third year may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.
Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Media and Digital Technologies assessed
Problem-solving not assessed

Domain C - Social Competencies

Communication not assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity not assessed

Domain D - Personal Competencies

Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management not assessed

402-2203-01L Classical Mechanics

W 7 credits 4V+2U R. Renner

Abstract
A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, spinning top, relativistic space-time structure, particles in an electromagnetic field, Hamiltonian mechanics, canonical transformations, integrable systems, Hamilton-Jacobi equation.

Objective
Fundamental understanding of the description of Mechanics in the Lagrangian and Hamiltonian formulation. Detailed understanding of important applications, in particular, the Kepler problem, the physics of rigid bodies (spinning top) and of oscillatory systems.

529-0051-00L Analytical Chemistry I

W 3 credits 3G D. Günther, M.-O. Ebert, G. Schwarz, R. Zenobi

Abstract
Introduction into the most important spectroscopical methods and their applications to gain structural information.

Objective
Knowledge about the necessary theoretical background of spectroscopical methods and their practical applications

Content
Application oriented basics of organic and inorganic instrumental analysis and of the empirical employment of structure elucidation methods:
- Mass spectrometry; Ionization methods, mass separation, isotope signals, rules of fragmentation, rearrangements.
- NMR spectroscopy: Experimental basics, chemical shift, spin-spin coupling.
- IR spectroscopy: Revisiting topics like harmonic oscillator, normal vibrations, coupled oscillating systems (in accordance to the basics of the related lecture in physical chemistry); sample preparation, acquisition techniques, law of Lambert and Beer, interpretation of IR spectra; Raman spectroscopy.
- UV/VIS spectroscopy: Basics, interpretation of electron spectra. Circular dichroism (CD) and optical rotation dispersion (ORD).

Prerequisites / notice
Exercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

529-0121-00L Inorganic Chemistry I

W 3 credits 2V+1U H. Grützmacher, P. Steinegger

Abstract
Discussion of syntheses, structures, and general reactivity of coordination compounds of the transition metals as well as the lanthanides and actinides. Introduction of methods of characterization, physical-chemical properties of coordination compounds as well as principles of radiochemistry.

Objective
The students will learn and understand the methodological basics of binding theory in complexes of transition metals. They will be able to explain the structure, chemical bonding, spectroscopic properties as well as general strategies for the synthesis of complexes of transition metals. The students will acquire knowledge on the fundamentals of radioactive decay and radiochemistry. Furthermore, they will be familiar with the basics of inorganic chemistry of lanthanides and actinides.

Content
This course consists of the following parts, which introduce the students to the chemistry of transition metals as well as lanthanides and actinides:
1) General definitions and terms in coordination chemistry; 2) Coordination numbers and structures; 3) Ligand types; 4) The chemical bond in coordination compounds part A: Crystal field theory and ligand field theory; 5) The chemical bond in coordination compounds part B: Qualitative MO theory; 6) Reactivity and reaction mechanisms of coordination compounds; 7) Group theory and character tables; 8) Properties and characterization of coordination compounds; 9) Introduction to radiochemistry; 10) Principles of the chemistry of the lanthanides and actinides.

Prerequisites / notice
Eine kommentierte Foliensammlung ist im HCI-Shop erhältlich.

Literature
Analytical Competencies assessed

C. Schär

Atmosphere

This lecture imparts the mathematical basis necessary for the development and application of Atmospheric Science, An Introductory Survey.

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Adaptability and Flexibility not assessed

M. A. Sprenger

Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Adaptability and Flexibility not assessed

Written information will be supplied.

A pdf file of the printed lecture notes is provided online. Supplementary material may be provided online.

The students are able to:
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Python (previous experience not necessary: a Python introduction is given). Example programs and graphics tools are supplied.

Lecture notes


List of literature is provided.

Organic Chemistry I

W 3 credits 2V+1U H. Wennenemers

Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetals, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Lecture notes

A pdf file of the printed lecture notes is provided online. Supplementary material may be provided online.

No set textbooks. Optional literature will be proposed at the beginning of the class and in the lecture notes.

Numerical Methods in Environmental Sciences

W 3 credits 2G C. Schär, C. Zeman

This lecture imparts the mathematical basis necessary for the development and application of numerical models in the field of Environmental Science. The lecture material includes an introduction into numerical techniques for solving ordinary and partial differential equations, as well as exercises aimed at the realization of simple models.

Classification of numerical problems, introduction to finite-difference methods, time integration schemes, non-linearity, conservative numerical techniques, an overview of spectral and finite-element methods. Examples and exercises from a diverse cross-section of Environmental Science.

Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Python (previous experience not necessary: a Python introduction is given). Example programs and graphics tools are supplied.

Lecture notes


List of literature is provided.

Weather Systems

W 3 credits 2G M. A. Sprenger, F. Scholder-Aemisegger

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Autumn Semester 2021
Page 1249 of 2152
### Atmospheric Physics

**Abstract**
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

**Objective**
- Students are able to explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics.
- To evaluate the significance of clouds and aerosol particles for artificial weather modification.

**Content**
The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clapeyron equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

- Students also learn to classify radiosondes with the help of the thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

- Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

- With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

- The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

**Lecture notes**
Powerpoint slides and chapters from the textbook will be made available on moodle: [https://moodle-app2.let.ethz.ch/course/view.php?id=15367](https://moodle-app2.let.ethz.ch/course/view.php?id=15367)

**Literature**

**Prerequisites / notice**
50% of the time we use the concept of "flipped classroom" ([en.wikipedia.org/wiki/Flipped_classroom](http://en.wikipedia.org/wiki/Flipped_classroom)), which we introduce at the beginning.

- We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

- There is a tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.

**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories
- Domain B - Method-specific Competencies: Analytical Competencies
- Domain C - Social Competencies: Communication
- Domain D - Personal Competencies: Critical Thinking

**Taught competencies**
- Self-direction and Self-management

### Pedosphere

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

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

**Content**
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions, soil fertility, land use and soil degradation.

**Lecture notes**
Polybook


**Prerequisites / notice**
Prerequisites: Basic knowledge in chemistry, biology and geology.

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### Laboratory Courses, Semester Papers, Proseminars, Field Trips

*Further laboratory courses must be applied for at the respective Director of Studies.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0011-04L</td>
<td>O</td>
<td>Practical Course General Chemistry</td>
<td>O</td>
<td>8</td>
<td>12P</td>
<td>H. V. Schönberg, E. C. Meister</td>
</tr>
</tbody>
</table>

*Latest online enrolment is 20.9.2021*

*Information about the practical course will be given on the first day.*

**Abstract**
Qualitative analysis (determination of cations and anions), acid-base-equilibria (pH-values, titrations, buffer), precipitation equilibria (gravimetry, potentiometry, conductivity), redoxreactions (syntheses, redox-titrations, galvanic elements), metal complexes (syntheses, complexometric titration), Analysis of measured data, vapour pressure, conductivity, calorimetry, solubility.
Students are accustomed to scientific work and they get to know one specific research field.

This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills. Manuals for the individual experiments are available in English.

529-0129-00L Inorganic and Organic Chemistry II

Abstract
Introduction to the experimental methods of Inorganic Chemistry

Objective
The teaching laboratory offers an insight into different aspects of Inorganic Chemistry, including solid state chemistry, organometallic chemistry, kinetics, etc. The synthesis, characterization and analysis of inorganic compound are a main topic. Special emphasis on experimental techniques of synthetic inorganic chemistry, in particular the safe handling of reactive and pyrophoric chemical and solvent purification and drying techniques.

Content
Inorganic chemistry part: Synthesis and analysis of elemento-organic compounds, metal complexes, and organometallic compounds. Introduction to Schlenk techniques, solid state synthesis, and kinetics. Introduction in the chemistry library: literature data banks and collections of spectra.

Organic synthesis with organometallic compounds and catalysts: Experiments in the framework of a selected specialised project. Possible projects: Rh catalysed asymmetric hydrogenation of enamides, Mn-catalysed epoxidation of olefins, Cu catalysed Diels-Alder reactions, synthesis of organo-boron compounds and Pd catalysed coupling with halides, Ru catalysed transfer hydrogenation.

A manual is distributed in the teaching laboratory.

Lecture notes
- Passed Basisprüfung
- Passed Practical Course General Chemistry (1. Semester, 529-0011-04)
- Passed Practical Course Inorg. and Org. Chemistry I (2. Sem., 529-0230)
- Continuous Attendance of Course Inorg. Chemistry I (3. Sem., 529-0121) and Analytical Chemistry 1 (3. Sem., 529-0051)

If necessary, access priority will be settled according to the results of the first-year examinations.

Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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

—— 5. Semester (Physical-Chemical Direction)

——— Laboratory Courses, Semester Papers, Proseminars, Field Trips

Further laboratory courses must be applied for at the respective Director of Studies.

Number Title Type ECTS Hours Lecturers
529-0450-00L Semester Project W 18 credits 18A Supervisors

Abstract
In a semester project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic.

Objective
Students are accustomed to scientific work and they get to know one specific research field.

402-0000-00L Physics Lab 3 W 7 credits 13P M. Donega, S. Gvasaliya

Abstract
This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills. Manuals for the individual experiments are available in English.
We offer experiments covering the following topics:

- Communication
- Analytical Competencies
- Moral and Ethical Competencies
- Self-direction and Self-management
- Integrity and Work Ethics
- Critical Thinking
- Creative Thinking
- Cooperation and Teamwork
- Problem-solving
- Techniques and Technologies
- Concepts and Theories
- Adaptable and Flexible

**Objective**

Students learn to independently perform advanced experiments and document them scientifically correctly.

Students are required to attend a safety lecture on the first day of the course and pass the corresponding online moodle-test before being allowed to access the laboratory rooms and perform the experiments.

The following aspects are emphasized:
- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

**Content**

We offer experiments covering the following topics:

Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

**Lecture notes**

Instructions for experiments are available in English.

**Prerequisites / notice**

From a variety of over 50 experiments, students have to perform 4 experiments covering different topics. The experimental work is complemented by writing a scientific report.

**Taught competencies**

- Domain A - Subject-specific Competencies
- Domain B - Method-specific Competencies
- Domain C - Social Competencies
- Domain D - Personal Competencies

**ECTS**

4 credits

**Lecturers**

J. Vorholt-Zambelli

**Number**

529-0400-00L

**Title**

Bachelor’s Thesis

**Type**

O

**ECTS**

15 credits

**Hours**

15D

**Lecturers**

Supervisors

**Objective**

It completes the Bachelor program and consists of a scientific project carried out independently.

Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

**Bachelor’s Thesis**

**Biochemical-Physical Direction**

**1. Semester (Biochemical-Physical Direction)**

**Compulsory Subjects First Year Examinations**

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### Literature


### Lecture notes

Copies of the course slides as well as other documents will be provided as pdf files via the moodle platform.

### Objective

Introduction to the chemistry of ionic equilibria: Acids and bases, redox reactions, formation of coordination complexes and precipitation reactions.

### Content

Chemical equilibrium and equilibrium constants, mono- and polyprotic acids and bases in aqueous solution, calculation of equilibrium concentrations, acidity functions, Lewis acids, acids in non-aqueous solvents, redox reactions and equilibria, Galvane cells, electrode potentials, Nernst equation, coordination chemistry, stepwise formation of metal complexes, solubility.

### Taught competencies

| Domain A - Subject-specific Competencies |
| Concepts and Theories |
| assessed |
| Techniques and Technologies |
| assessed |
| Domain B - Method-specific Competencies |
| Analytical Competencies |
| assessed |
| Decision-making |
| not assessed |
| Media and Digital Technologies |
| not assessed |
| Problem-solving |
| assessed |
| Project Management |
| not assessed |
| Domain C - Social Competencies |
| Communication |
| not assessed |
| Cooperation and Teamwork |
| not assessed |
| Customer Orientation |
| not assessed |
| Leadership and Responsibility |
| not assessed |
| Self-presentation and Social Influence |
| not assessed |
| Sensitivity to Diversity |
| not assessed |
| Negotiation |
| not assessed |
| Adaptability and Flexibility |
| not assessed |
| Creative Thinking |
| assessed |
| Critical Thinking |
| assessed |
| Integrity and Work Ethics |
| assessed |
| Self-awareness and Self-reflection |
| assessed |
| Self-direction and Self-management |
| assessed |

### Literature

Objective
Die Studierenden sind nach der Vorlesung in der Lage,
- mit für die Chemie wichtigen physikalischen Grössen und deren Einheiten zu rechnen,
- einige Eigenschaften chemisch relevanter Teilchen zu benennen und experimentelle Methoden zur Bestimmung dieser Eigenschaften vorzuschlagen,
- Anwendungen und Gefahren der Radioaktivität zu benennen,
- radioaktive Zerfallsprozesse und den zeitlichen Verlauf von einfachen Zerfallsreaktionen mathematisch wiederzugeben sowie qualitativ vorherzusagen und darzustellen,
- Wellen- und Teilchenmodelle von elektromagnetischer Strahlung und Materie zu beschreiben und experimentelle Methoden zu deren Nachweis vorzuschlagen,
- die Grundlagen der Quantenmechanik (Bedeutung der Wellenfunktion, Heisenbergsche Unschärferelation, Operatoren, Kommutatoren) zu erklären und einfache Rechnungen damit auszuführen,
- Absorptions- und Emissionspektren von Eiweißkörpern zu analysieren und zu berechnen,
- die Schrödingergleichung für ein molekulares Mehrteilchensystem aufzustellen,
- die Molekülschwingungen von zweiatomigen Molekülen mit dem Modell des harmonischen und des anharmonischen Oszillators zu modellieren,
- das Konzept eines Orbitals zu erklären und die qualitative Form der Orbitale des Wasserstoffatoms mathematisch und bildlich wiederzugeben,
- den Aufbau des Periodensystems der Elemente mit Hilfe des Orbitalkonzepts zu erklären,
- Ähnlichkeiten in der elektronischen Struktur von Atomen zu erkennen und zu benutzen, um chemisch relevante Eigenschaften vorherzusagen, und
- Termssymbole für atomare Grundzustände aufzustellen.

Content
Atomic structure and structure of matter: atomic theory, elementary particles, atomic nuclei, radioactivity, nuclear reactions. Atomic Orbitals and energy levels: ionisation energies, atomic spectroscopy, term values and quantum numbers. Quantum mechanical atom model: wave-particle duality, the uncertainty principle, Schrödinger's equation, the hydrogen atom, construction of the periodic table of the elements. Chemical bonding: ionic bonding, covalent bonding, molecular orbitals. Qualitative analysis (determination of cations and anions), acid-base-equilibria (pH-values, titrations, buffer), precipitation equilibria (gravimetry, potentiometry, conductivity), redox reactions (syntheses, redox-titrations, galvanic elements), metal complexes (syntheses, complexometric titration).

Prerequisites / Literature
Maturastoff. Insbesondere Integral- und Differentialrechnung.

Taught Competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Assessed

Additional First Year Compulsory Subjects

### 3. Semester (Biochemical-Physical Direction)

Examination Block

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0373-00L</td>
<td>Mathematics III: Partial Differential Equations</td>
<td>O</td>
<td>4</td>
<td>2+1U</td>
<td>A. Carlotto</td>
</tr>
</tbody>
</table>

Abstract

Objective
Classical tools to solve the most common linear partial differential equations.
1) Examples of partial differential equations
   - Classification of PDEs
   - Superposition principle

2) One-dimensional wave equation
   - D'Alembert's formula
   - Duhamel's principle

3) Fourier series
   - Representation of piecewise continuous functions via Fourier series
   - Examples and applications

4) Separation of variables
   - Solution of wave and heat equation
   - Homogeneous and inhomogeneous boundary conditions
   - Dirichlet and Neumann boundary conditions

5) Laplace equation
   - Solution of Laplace's equation on the rectangle, disk and annulus
   - Poisson formula
   - Mean value theorem and maximum principle

6) Fourier transform
   - Derivation and definition
   - Inverse Fourier transformation and inversion formula
   - Interpretation and properties of the Fourier transform
   - Solution of the heat equation

7) Laplace transform (if time allows)
   - Definition, motivation and properties
   - Inverse Laplace transform of rational functions
   - Application to ordinary differential equations

Lecture notes
See the course web site (linked under Lernmaterialien)

Literature

Additional books:
4) E. Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons (chapters 1,2,11,12,6)

For additional sources, see the course web site (linked under Lernmaterialien)

Prerequisites / notice
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the written exam, the results of the exercises are taken into account when evaluating the results of the exam (compulsory performance component, 12% of the exam mark; in case of repetition of the exam, the exercise marks from a previous semester can be kept).

For more information about the lecture: www.csms.ethz.ch/education/Iinfol

529-0001-00L Introduction to Computer Science
W 4 credits 2V+2U  P. H. Hünenberger

Abstract
Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation.

Objective
Acquire a starting package concerning the computational aspects of natural sciences; discuss fundamentals of computer architecture, languages, algorithms and programming with an eye to their application in the area of chemistry, biology and material science.

Content
Lecture: Introduction to UNIX, introduction to C++ programming, data representation and processing, computational errors, algorithms and scaling, sorting and searching, numerical algorithms, algorithmic strategies, computer simulation, computer architecture, operating systems, programming languages, computer networks, databases, representation of chemical structures, molecular simulation; Exercises: Make students familiar with the UNIX operating system, C++ programming techniques, simple algorithms and computational applications in chemistry by means of exercise series at the computer.

Lecture notes
Script booklet (copies of powerpoint slides, in English), distributed at first or second lecture.

See: www.csms.ethz.ch/education/Iinfol

252-0027-00L Introduction to Programming
W 7 credits 4V+2U  T. Gross

Abstract
Introduction to fundamental concepts of modern programming and operational skills for developing high-quality programs, including large programs as in industry. The course introduces software engineering principles with an object-oriented approach based.
Objective
Many people can write programs. The "Introduction to Programming" course goes beyond that basic goal: it teaches the fundamental concepts and skills necessary to perform programming at a professional level. As a result of successfully completing the course, students master the fundamental control structures, data structures, reasoning patterns and programming language mechanisms characterizing modern programming, as well as the fundamental rules of producing high-quality software. They have the necessary programming background for later courses introducing programming skills in specialized application areas.

Content
Basics of object-oriented programming. Objects and classes. Pre- and postconditions, class invariants, design by contract. Fundamental control structures. Assignment and references. Fundamental data structures and algorithms. Recursion. Inheritance and interfaces, basic concepts of Software Engineering such as the software process, specification and documentation, debugging, reuse and quality assurance.

Lecture notes
The lecture slides are available for download on the course page.

Literature
See the course page for up-to-date information.

Prerequisites / notice
There are no special prerequisites. Students are expected to enroll in the other courses offered to first-year students of computer science.

529-0422-00L Physical Chemistry II: Chemical Reaction Kinetics

Abstract

Objective
Introduction to Chemical Reaction Kinetics

Content

Literature

Prerequisites / notice
Voraussetzungen:
- Mathematik I und II
- Allgemeine Chemie I und II
- Physikalische Chemie I

529-0221-00L Organic Chemistry I

Abstract
Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, acetalas, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Objective
Acquisition of a basic repertoire of synthetic methods including important reactions of aldehydes, ketones, carboxylic acids and carboxylic acid derivatives, as well as eliminations and fragmentations. Particular emphasis is placed on the understanding of reaction mechanisms and the correlation between structure and reactivity. A deeper understanding of the concepts presented during the lecture is reached by solving the problems handed out each time and discussed one week later in the exercise class.

Content
Chemical reactivity and classes of compounds. Eliminations, fragmentations, chemistry of aldehydes and ketones (hydrates, hydrols, imines, enamines, nucleophilic addition of organometallic compounds, reactions with phosphorus and sulfur ylides; reactions of enolates as nucleophiles) and of carboxylic acid derivatives. Aldol reactions.

Lecture notes
A pdf file of the printed lecture notes is provided online. Supplementary material may be provided online.

Literature
No set textbooks. Optional literature will be proposed at the beginning of the class and in the lecture notes.

5. Semester (Biochemical-Physical Direction)

Laboratory Courses, Semester Papers, Proseminars, Field Trips
Further laboratory courses must be applied for at the respective Director of Studies.

Bachelor's Thesis

Second and Third Year Additional Subjects
The Bachelor's programme in Interdisciplinary Sciences allows students to choose from any subject taught at a Bachelor level at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the 2nd year. See the Programme Regulations 2010/2018 for further details.

Other Electives ETH
Further combinations of compulsory elective subjects arising upon specific written request by the students and permission by the Director of studies.

GESS Science in Perspective

Science in Perspective
see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-CHAB.

Language Courses
### Interdisciplinary Sciences Bachelor - Key for Type

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

### Key for Hours

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

### ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Interdisciplinary Sciences Master

The Master's programme in Interdisciplinary Sciences allows students to choose from any subject taught at the Master's level at ETH Zurich.

In consultation with the Director of Studies of Interdisciplinary Sciences, every student must establish his/her own individual study programme at the beginning of the Master's programme. See the Programme Regulations 2007/2020 for further details.

▸ Majors

The following list provides various Majors that can be chosen from: https://ethz.ch/content/dam/ethz/special-interest/chab/chab-dept/studies/documents/in/wl_in_sr19192101_en.pdf

In addition it is possible to create an individual Major in accordance with the Programme Regulations (Art. 19 paragraph 3).

▸ General Courses

Selection of courses from entire course catalogue of ETH, according to individual study plan

▸ Proseminars, Laboratory Courses, Research Projects and Sem. Papers

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0020-00L</td>
<td>Research Project</td>
<td>W</td>
<td>20 credits</td>
<td>20A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract: In a research project students extend their knowledge in a particular field, get acquainted with the scientific way of working, and learn to work on an actual research topic. Research projects are carried out in a core or optional subject area as chosen by the student.

Objective: Students are accustomed to scientific work and they get to know one specific research field.

Selection of courses from entire course catalogue of ETH, according to individual study plan

▸ GESS Science in Perspective

see GESS Science in Perspective: Language Courses ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-CHAB.

▸ Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-1000-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>20 credits</td>
<td>43D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

Abstract: In the Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student.

Objective: In the Master's Thesis students prove their ability to independent, structured and scientific working.

529-1000-30L   Master's Thesis

Only students who fulfill the following criteria are allowed to begin with their Master's thesis:

a. successful completion of the Bachelor's programme;
b. fulfilling of any additional requirements necessary to gain admission to the Master's programme.

Duration of the Master's Thesis: 4 months.

Abstract: In the Master's thesis students prove their ability to independent, structured and scientific working. The Master's thesis is usually carried out in a core or optional subject area as chosen by the student.

Objective: In the Master Thesis students prove their ability to independent, structured and scientific working.

Duration of the Master's Thesis 6 months, possible only with permission of the Director of Studies.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-1000-30L</td>
<td>Master's Thesis</td>
<td>W</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
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</tbody>
</table>

Abstract: In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is usually carried out in a core or optional subject area as chosen by the student.

Objective: In the Master Thesis students prove their ability to independent, structured and scientific working.

Interdisciplinary Sciences Master - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>O</td>
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</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The course unit consists of the three courses "Climate", "Water" and "Soil", which are organized in modules.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
Lectures, exercises and excursions serve as an introduction to atmospheric sciences, hydrology and soil science. Students gain a broad vision of the cutting edge topics that are being researched and studied at the Department of Environmental Systems Science at ETH, Eawag, WSL a.o. This will be the base for a future dialog between the field of landscape architecture and the field of sciences.

Objective
Students acquire basic knowledge in atmospheric sciences, hydrology and soil science:
- Understanding basic chemical and physical processes in the atmosphere that influence weather and climate
- Knowledge of water balance, principles of integral water management and climatic factors in the field of hydrology
- Fundamentals about the classification of soils, soil-forming processes, physical and chemical soil properties, soil biology and ecology, soil degradation and protection

Students develop an understanding of the relevance of these topics in the field of landscape architecture. Temporal and physical scale, research methods, units of measurement, lexicon, modes of representation and critical literature form the framework for the joint discourse.

Content
The course unit consists of the three courses "Climate", "Water" and "Soil", which are organized in modules.

Module 1 "Climate", 20.–24.09.2021
- Atmospheric dynamics: weather conditions, precipitation formation, weather forecast
- Climate physics: past and future changes in global climate and scenarios for Switzerland
- Land-climate dynamics: interaction between the land surface and the climate system
- Hydrology and water cycle: extreme precipitation, influence of climate change on the cryosphere
- Atmospheric chemistry: aerosols, greenhouse gases, air pollution
- Introduction to soils: definition, function, formation and classification and mapping
- Soil physics: soil texture, soil structure, soil water potentials, hydraulic conductivity
- Soil chemistry and fertility: clay minerals and oxides, cation exchange capacity, soil pH, essential plant nutrients
- Soil biology and ecology: soil fauna and microflora, fungi, bacteria, food web, organic matter
- Soil degradation and threats to soil resources: erosion, compaction, sealing, contamination, salinization
- Practical aspects of soil protection

Hydrological profile of the northern side of the Alps:
- Alpine region (Grisel area): dominate role of snow and ice, dangerous processes, liquefaction of the water balance in the wake of climate change, uses (hydropower) and conflicts of use, new images of the Alpine region
- From the Alps to the Mittelland (locations along the Aare): Lake Thun (role of lakes in the water cycle, river and lake shore planning), Uetikon (conflicts of use between groundwater use, flood protection, revitalization and modes of transport) & Seeland (Jura water correction, conflicts of use in the Seeland)
- Jura (Reigoldswil region): Jurassic landforms, water in the karst, water supply in the karst

Module 2 "Water", 27.09.–1.10.2021
Basics:
- Water supply: water balance, groundwater, water quality (water protection)
- Hydrological hazards: floods and drought
- Water use: drinking water, hydropower, ecology
- External influencing factors: human influence in the historical dimension, global change

Module 3 "Soil", 4.10.–8.10.21
- Introduction to soils: definition, function, formation, classification and mapping
- Soil physics: soil texture, soil structure, soil water potentials, hydraulic conductivity
- Soil chemistry and fertility: clay minerals and oxides, cation exchange capacity, soil pH, essential plant nutrients
- Soil biology and ecology: soil fauna and microflora, fungi, bacteria, food web, organic matter
- Soil degradation and threats to soil resources: erosion, compaction, sealing, contamination, salinization
- Practical aspects of soil protection

Lecture notes
The course material includes a reading list.

Literature
The course material includes a reading list.

Prerequisites / notice
The courses "Climate", "Water" and "Soil" are organized with the Fundamental Studio I as joint one-week modules. The weekly schedules will be provided with the course materials.

Module 1 "Climate", 20.–24.09.2021
Module 2 "Water", 27.09.–1.10.2021
Module 3 "Soil", 4.10.–8.10.21

- The courses are held in English or German.
- The written session examination covers all three courses "Climate", "Water" and "Soil".
- During the excursions there will be at least one external overnight stay.

Teaching competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

This course introduces ecology and plant sciences. Through lectures, exercises and excursions, students will gain a broad vision of the cutting edge topics that are being researched and studied at the Department of Environmental Systems Science at ETH. This will be the base for a future dialog between the field of landscape architecture and the field of sciences.

**Objective**

Students acquire basic knowledge in ecology and plant sciences focusing in its application in the field of landscape architecture. Temporal and physical scale, research methods, units of measurement, lexicon, modes of representation and critical literature form the framework for the joint discourse.

**Content**

The fundamental course “Ecology and Plant Sciences” is an introduction to the field of living systems, starting with the history of ecology, followed by an introduction to plant systematics, taxonomy and physiology. The course will also introduce students to the specifics of grassland systems and forests. Lastly, the course will focus on the specifics of tree structure and function.

**Lecture notes**

Course material will be provided.

**Literature**

The course material includes a reading list.

**Prerequisites / notice**

The fundamental course is organized with the Fundamental Studio I as a joint two-week module. The weekly schedule is provided with the course documents.

Module 4 "Ecology and Plant Sciences", 11.10.–22.10.2021

The course is held in English or German.

---

This fundamental course provides an introduction to the basics of botany and forms a solid foundation of knowledge for the following semesters. The course covers the following areas: Species knowledge of native shrubs and trees in autumn and winter conditions and their habitat requirements, introduction to the identification of plants and consolidation of botanical terms.

**Objective**

Students will be introduced to botany and after the course they will be able to identify about sixty native trees and shrubs in order to use them appropriately in their designs. They will be familiar with botanical terms, which will enable them to have a high level of understanding of botanical literature.

**Content**

This course focuses on excursions with a botanical expert. In addition, the students are supported by theoretical and conceptual lectures. This gives the students a good basis of botanical knowledge, which can be professionally integrated into their designs. This module is organized together with the Foundation Studio I, so that the knowledge imparted can directly influence their designs. In the morning they are taught in botany and in the afternoon they work on their designs.

The module is divided into different subject areas:

1) Consolidation of botanical terms. These form the basis for the identification and recognition of plants. The most important technical terms are explained and illustrated with suitable plant material.

2) Species knowledge is taught on regular field excursions and supplemented with theoretical input. The species can also be studied in the classroom using fresh material. In addition to site characteristics and seasonal changes, growth forms are also taught.

3) Through the introduction to identification, the students will understand how a simple identification key is constructed and how it is used, so that unknown species can be identified independently.

**Lecture notes**

The relevant literature and content for the examination will be indicated during the course.

**Prerequisites / notice**

The detailed course schedule is published on the course website (and is included in the reader).

The lectures might take place outside. It is necessary to foresee clothes adapted to the weather.

---

**061-0105-00L Designing with Plants I**

*Only for Landscape Architecture MSc.*

**Abstract**

This fundamental course provides an introduction to the basics of botany and forms a solid foundation of knowledge for the following semesters. The course covers the following areas: Species knowledge of native shrubs and trees in autumn and winter conditions and their habitat requirements, introduction to the identification of plants and consolidation of botanical terms.

**Objective**

Students will be introduced to botany and after the course they will be able to identify about sixty native trees and shrubs in order to use them appropriately in their designs. They will be familiar with botanical terms, which will enable them to have a high level of understanding of botanical literature.

**Content**

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The module is divided into different subject areas:

1) Consolidation of botanical terms. These form the basis for the identification and recognition of plants. The most important technical terms are explained and illustrated with suitable plant material.

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3) Through the introduction to identification, the students will understand how a simple identification key is constructed and how it is used, so that unknown species can be identified independently.

**Lecture notes**

The notes or reader will be distributed during the course.

**Literature**

The relevant literature and content for the examination will be indicated during the course.

**Prerequisites / notice**

The detailed course schedule is published on the course website (and is included in the reader).

The lectures might take place outside. It is necessary to foresee clothes adapted to the weather.
The fundamental course discusses current constructive problems in landscape architecture as part of the complex and multi-faceted urban space that is cultivated and animated by humans. The two parts of the lecture (Materials and Construction I and II) are designed as complementary modules.

Objective
The students learn comprehensive skills in dealing with constructive questions (regarding the topics of soil, water and topography). The goal is to promote a value-based critical and research-based thinking that is the prerequisite for discovering new questions and developing independent solutions.

Content
The course Materials and Construction I deals with constructive questions around the topic of soil, water and topography. The introductory lecture introduces the two parts of the lecture (Materials and Construction I and II) as a whole and illustrates with concrete examples how thinking about constructive possibilities co-determine and penetrate the design process.

Subsequently, in addition to principles in dealing with soil (floor structures, surface treatment) and water (physical state, element dynamics), a wide range of topics are discussed. These deal with current questions of today's urban landscapes in dealing with contaminated soil, flood protection, drinking water management, etc. The topic of topography represents the continuous and connecting moment.

The fundamental course Materials and Construction I (15th November – 26th November 2021) is closely linked to the foundation studio I. The weekly schedule is published on the course website (and is included in the reader).

Lecture notes
The reader will be distributed on Friday, 12th November 2021.

Literature
The reader contains all relevant literature (also relevant for the exam).

Prerequisites / notice
The course is aimed exclusively at the students of the master's programme in landscape architecture.

The detailed course schedule is published on the course website (and is included in the reader).
### Content

Designing nature accompanies the history of mankind. Since industrialisation and with the establishment of landscape architecture as a profession, the understanding of nature and design concepts have changed from the green lung of cities to the current saving of the planet in the Anthropocene. The course deals with the relevant phenomena of designing nature (park, garden city, garden reform, new gardens, modern gardens, natural gardens, postmodern parks and landscapes, ecosystem repair, urban agriculture, slum upgrading, nature-cultures, etc.), terms (nature, landscape, garden, ecology, agriculture, etc.) and their wider contexts. Based on the history and theory of the profession, students develop a strong fundament for designing in the present.

### Lecture notes

Course material will be provided.

### Literature

The course material includes a reading list.

### Prerequisites / notice

The course takes place as a block course alternating with "Ethics in Landscape Architecture".

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught</th>
<th>Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Taught</td>
<td>Notice</td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Taught</td>
<td>Notice</td>
</tr>
<tr>
<td>Communication</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Taught</td>
<td>Notice</td>
</tr>
<tr>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

### 061-0111-00L Ethics in Landscape Architecture

**Objective:**

This course covers basic positions of philosophical ethics with a strong emphasis on central debates in landscape architecture.

**Content:**

Between the poles of theory and practice and through the development of a foundation in ethics, the students' sensitivity for ecological, political and social issues will be awakened and strengthened. In response to current issues touched upon in the disciplinary media or journalism, we will reflect upon the role of landscape architects in today's society as well as one's own individual attitude within the profession. The overall goal is for students to gain a critical understanding of a range of design approaches as well as an awareness of the specific role of design and design quality in the context of ethical debates.

Texts will be read in German and English.

### Lecture notes

Detailed information regarding the course will be communicated at the beginning of the semester.

Course material will be provided.

### Literature

The course material includes a reading list.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught</th>
<th>Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Taught</td>
<td>Notice</td>
</tr>
<tr>
<td>Communication</td>
<td>assessed</td>
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</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>assessed</td>
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</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Taught</td>
<td>Notice</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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</tr>
</tbody>
</table>

### 061-0113-00L Digital Design Methods I

**Abstract:**

This course introduces digital design methods in landscape architecture from data acquisition and modelling, to simulation and visualization.

**Objective:**

Students know the most relevant survey methods, landscape modelling tools as well as simulation and visualization techniques. They are able to use those methods independently in the following semesters and in practice.

**Content:**

Based on a case study, the students work on the entire workflow of a landscape architectural project:

- From data collection in the field to 2D and 3D modelling in the Landscape Visualization and Modelling Lab (LVML), analysis and simulation with various software solutions to visualizations and physical prototypes, this course covers the most important digital methods in landscape architecture.

The course is divided into three parts:

1. Survey
2. Modelling
3. Analysis, Simulation, Visualization

The case study will serve as a synthesis project where the students can apply their acquired skills. During the course, students are supported by an interdisciplinary team in the development of their case study. The case study will be conducted in teams of two students.

**Lecture notes**

Digital and physical learning material is provided throughout the course.
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking
- Self-awareness and Self-reflection

Core Courses
The core courses build on the basic courses and convey basic, broad knowledge in the core areas of landscape architecture in relation to design lessons. Some of the core courses are compulsory and some are freely selectable. Further details, in particular about taking these subjects, for performance assessments and for compensating for failed subjects, are regulated in Art. 27 and Art. 31 Paragraph 4.

Compulsory Core Courses
Courses are offered in Spring Semester.

Elective Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>052-0569-21L</td>
<td>Lecture Series Design and Architecture of ...</td>
<td>W</td>
<td>2 credits</td>
<td>1V</td>
<td>E. Christ, A. Caruso, C. Kerez, E. Mosayebi</td>
</tr>
</tbody>
</table>

Abstract
Specialists give lectures on current architecture-specific topics.

Objective
Obtaining knowledge from architectural practice after 2020.

Content
Specialists give lectures on current architecture-specific topics.

Prerequisites / notice
The lecture series take place on Tuesdays from 6-8 pm in HIL E4 (s. room reservations):

Speakers:
- 28.09.21: Prof. Patrick Heiz
- 05.10.21: PD Dr. Erik Wegerhoff - Note: This lectures takes place in the HIL underground carpark (follow the signs!)
- 12.10.21: Prof. Mike Guyer
- 02.11.21: Prof. Freek Persyn (ONA E7 Focushalle, Oerlikon)
- 16.11.21: GD Roger Boltshauser
- 30.11.21: GD Angela Deuber
- 07.12.21: Prof. Alexandre Theriot

Compensatory Course for Core Courses
In the first semester of the curriculum no compensation courses for compulsory courses offered.

Advanced Courses
In the first semester of the curriculum there are no main courses offered.

Design Studios
The design studios deal with problem and practice-related tasks on a local, regional, supra-regional, national and international level. Teaching of digital analysis, design and planning methods.

Foundation Studio I and II
- Fundamental Studio I: basic knowledge;
- Fundamental Studio II: Design tasks in the context of the contemporary landscape;

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>061-0141-21L</td>
<td>Foundation Studio I □</td>
<td>O</td>
<td>14 credits</td>
<td>26U</td>
<td>G. Vogt</td>
</tr>
</tbody>
</table>

Abstract
Only for Landscape Architecture MSc.
Classes and critiques are held in English and German.

Objective
Students acquire basic analytical, design and methodological skills in the field of Landscape Architecture.

Content
The course introduces to the subject and complexity of the urbanized landscape and teaches the critical engagement with the challenges and potentials of current tendencies in Landscape Architecture. On the basis of theoretical inputs and short design exercises the students will develop analytical, methodical and design skills.

Module 1 “Climate”, 20.–24.09.2021
Module 2 “Water”, 27.09.–1.10.2021
Module 3 “Soil”, 4.10.–8.10.21
Module 4 “Ecology and Plant Sciences”, 11.10.–22.10.21
Module 5 “Designing with Plants I”, 1.11.–12.11.21
Module 6 “Materials and Construction I”, 15.11.–26.11.21
Module “Synthesis”, 29.11.–22.12.21

In addition to the design professors, external experts of diverse fields will advise and support the students during the development of their design. The organization of the course intends to have lectures and other theoretical inputs in the morning (fundamental courses) and to deal with the same topics in more discursive way in the design studio in the afternoon.
The workbook will be handed in during the first semester week. The relevant literature is included in the workbook.

- The weekly schedule is published on the course website (and is included in the reader).
- Classes (and critiques) are held in English and German.

### Taught Competencies

#### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

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

#### Domain C - Social Competencies
- Communication: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

#### Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

#### Advanced Studio

**Complex design tasks involving social, topographical, hydrological and ecological issues.**

The advanced studio will be offered as of Spring Semester 2022.

#### Seminar Week and Internship Report

**In MScLA at least one week of seminar must be completed.**

Furthermore, part of the course is a six-month internship in the field of landscape architecture, the achievements (work phases, learning success) must be documented in an internship report.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>061-0151-21L</td>
<td>Seminar Week Autumn Semester 2021</td>
<td>W</td>
<td>2 credits</td>
<td>3S</td>
<td>S. Hassold, G. Vogt</td>
</tr>
</tbody>
</table>

**Abstract**

Along five walks we explore the city vegetation of Basel and built connections to the conditions of the surrounding landscape. Obtaining a panoptical view of the "nature of the city" is the goal of intensive study of the territory.

**Objective**

In addition to a comprehensive insight into the vegetation of the city of Basel, the students receive an introduction to the method of walking as a way of exploring the urban landscape from a pedestrian perspective.

**Content**

Five walks lead us through the territory of the city of Basel. The tri-national area (Germany, Switzerland, France) with its exceptional geological, topographical, hydrological and climatic situation has a specific and diverse vegetation. We discover this diversity on the walks in the Petite Camargue, on the Tüllinger Hügel, during the crossing of the Jura and in the parks within the city.

The walks are led by proven experts. In conversations, Sonja Hassold (biologist), Günther Vogt (landscape architect) and Markus Ritter (ecologist) explain the relationships between the vegetation found and the conditions of the landscape. In doing so, references are made to the political, social and economic influencing factors that regulate the development of the landscape and significantly influence its shape.

The program is contextualized by dealing with the topic of walking science. Markus Ritter introduces the theory and method of promenadology in evening lectures, seminars and reading sessions, focusing on the person of Lucius Burckhardt (sociologist, 1925 - 2003).

**Lecture notes**

The reader will be given at the introductory course.

**Literature**

All relevant literature is included in the reader.

**Prerequisites / notice**

The weekly schedule is included in the reader.

The costs for the seminar trip (24.10.-30.10.) range between 251.- and 500.- (cost framework B). Included are: All overnight stays (including breakfast), a dinner together, transfers from the hotel to the excursions, reader and all costs for admission to museums.

The course is aimed exclusively at students of the master's program in landscape architecture.

It is highly recommended to participate this Seminar Week in preparation for the Module 5 (061-0105-00L Designing with Plants I) and the lecture Designing with Plants II (061-0106-00L)
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Problem-solving: assessed
- Project Management: not assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: not assessed

061-0153-00L  Internship Report
Only for Landscape Architecture MSc.

Abstract
Part of the course is a six-month internship in the field of landscape architecture. The internship should include as many work phases as possible in the work of a landscape architect. The students prepare an internship report in which they describe the various internship activities in detail and reflect on the learning success.

Objective
The internship report should cover as many work phases as possible in the work of a landscape architect.

Content
Part of the course is a six-month internship in the field of landscape architecture. The internship should include as many work phases as possible in the work of a landscape architect. The students prepare an internship report in which they describe the various internship activities in detail and reflect on the learning success.

Prerequisites / notice
Internship report (of 6 months, within the field of landscape architecture). The report can be written in German or English language.

► Science in Perspective
Courses of the "Science in Perspective" programme have to be completed (details see study guidelines Art. 27).

see GESS Science in Perspective: Language Courses
ETH/UBH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-ARCH.

► Master's Thesis
The master's thesis is the successful completion of the course. It confirms the ability to work independently in the field of landscape architecture and is tutored by D-ARCH professors (for details see Art. 30 of the study regulations).

Number  Title Type ECTS Hours Lecturers
061-0900-00L  Master's Thesis
Only students who fulfill the following criteria are allowed to begin with their master thesis:
a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract
The master's thesis concludes the course. It shows the ability of the students to do independent design work and is proof of the successful completion of their studies. It is under the direction of professors from D-ARCH.

Objective
The processing time for the master's thesis is fourteen weeks.
<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Educational Science

**Number** | **Title**                              | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
851-0240-00L | Human Learning (EW1)  
This lecture is only apt for students who intend to enrol in the programs "Teaching Diploma" or "Teaching Certificate". It is about learning in childhood and adolescence.  
Abstract: This course looks into scientific theories and also empirical studies on human learning and relates them to the school.  
Objective: Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.  
Lecturer: E. Stern  
ECTS: 2  
Lecture notes: Folien werden zur Verfügung gestellt.  
- Get to know cognitively activating instructions in MINT subjects  
- Get information about recent literature on learning and instruction  
- Get to know intelligence tests  
- Get information on the way humans process information and on human behaviour  
- Get information about recent literature on learning and instruction

851-0242-06L | Cognitively Activating Instructions in MINT Subjects  
Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).  
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".  
Abstract: This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.  
Objective:  
- Get to know cognitive activating instructions in MINT subjects  
- Get information about recent literature on learning and instruction  
Prerequisites / notice: Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin gesucht.  
Lecturer: R. Schumacher  
ECTS: 2  
Lecture notes: Folien werden zur Verfügung gestellt.  
Literature:  

851-0242-07L | Human Intelligence  
Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).  
Number of participants limited to 30.  
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".  
Abstract: The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.  
Objective:  
- Understanding of research methods used in the empirical human sciences  
- Getting to know intelligence tests  
- Understanding findings relevant for education  
Lecturer: E. Stern  
ECTS: 1  
Lecture notes: Folien werden zur Verfügung gestellt.  
Literature:  

851-0242-08L | Research Methods in Educational Science  
Number of participants limited to 30.  
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW 1)".  
Abstract: Literature from the learning sciences is critically discussed with a focus on research methods. At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.  
Objective:  
- Understand research methods used in the empirical educational sciences  
- Understand and critically examine information from scientific journals and media  
- Understand pedagogically relevant findings from the empirical educational sciences  
Lecturer: P. Edelsbrunner, T. Braas, C. M. Thurn  
ECTS: 1  
Lecture notes: Folien werden zur Verfügung gestellt.  
Literature:  

851-0240-22L | Coping with Psychosocial Demands of Teaching (EW4 W DZ)  
Number of participants limited to 20.  
The successful participation in EW1 ("Human Learning") and EW2 ("Designing Learning Environments for School") is recommended, but not a mandatory prerequisite.  
Lecturer: U. Markwalder, S. Maurer, S. Peteranderl-Rüschoff  
ECTS: 2  
Lecture notes: Folien werden zur Verfügung gestellt.  
Literature:  
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching

- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher’s work.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

Prerequisites / notice
Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

Subject Didactics and Professional Training

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-9020-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>W</td>
<td>6</td>
<td>13P</td>
<td>G. Kaufmann</td>
</tr>
<tr>
<td></td>
<td>Food Science</td>
<td></td>
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<tr>
<td></td>
<td>The teaching internship can just be visited if all other courses of TC are completed. Repetition of the teaching internship is excluded even if the examination lessons are to be repeated.</td>
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<tr>
<td></td>
<td>Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.</td>
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<td></td>
<td>- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.</td>
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<td>- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.</td>
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<td>- They learn the skills of the teaching trade.</td>
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<td>- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.</td>
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<td>- They learn to assess pupils’ work.</td>
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<td></td>
<td>- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.</td>
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</tr>
</tbody>
</table>

Literature
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Further Subject Didactics

For students enrolled from HS 2019: The courses offered here are credited under the category «Subject Didactics and Professional Training».

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-9005-00L</td>
<td>Mentored Work Specialised Courses in the Respective O</td>
<td>2 credits</td>
<td>4A</td>
<td></td>
<td>G. Kaufmann, K. Koch, U. Lerch</td>
</tr>
<tr>
<td></td>
<td>Subject with an Educational Focus Food Sc.</td>
<td></td>
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<tr>
<td></td>
<td>In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>The aim is for the students</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.</td>
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<td></td>
<td>- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.</td>
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<td></td>
<td>- To try out different options for specialist further training in their profession.</td>
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</tr>
</tbody>
</table>
Themen Schwerpunkte:

Lernformen:

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

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

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

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<table>
<thead>
<tr>
<th>Food Science TC - Key for Type</th>
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<tbody>
<tr>
<td>O</td>
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<td>W+</td>
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<td>W</td>
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<td>Z</td>
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<tr>
<td>Dr</td>
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<tr>
<th>Key for Hours</th>
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<tbody>
<tr>
<td>V</td>
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<td>G</td>
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<tr>
<td>U</td>
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<td>A</td>
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<td>D</td>
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<td>R</td>
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</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Food Science Master

Major in Food Processing

Disciplinary Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-3103-00L</td>
<td>Food Rheology I</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>P. A. Fischer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.</td>
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<tr>
<td>Objective</td>
<td>The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.</td>
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<tr>
<td>Content</td>
<td>Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).</td>
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<tr>
<td>Literature</td>
<td>Notes will be handed out during the lectures.</td>
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</table>

| 752-2003-00L  | Selected Topics in Food Technology                           | W+   | 3    | 2V    | R. Stadler, R. Behringer |
| Abstract      | Part 1 of the course deals with global market trends, food technologies, food health benefits. Physical and chemical fundamental knowledge help grasp the molecular composition of food. Part 2 entails management of risks across the food supply chain. The focus is on technological solutions to mitigate hazards, as well as their management upstream. |      |      |       |                 |
| Objective     | The objectives of the course are for students to understand the key drivers (market and consumer trends, health benefits, sustainability, etc.) that impact innovation in a food business environment. The course also illustrates food safety and quality considerations across the whole supply chain, using concrete examples and how certain technologies assist in reducing or eliminating food safety risks. |      |      |       |                 |
| Content       | Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products. |      |      |       |                 |
| Literature    | Notes will be handed out during the lectures.                |      |      |       |                 |

| 752-2314-00L  | Physics of Food Colloids                                     | W+   | 3    | 2V    | P. A. Fischer, R. Mezzenga |
| Abstract      | In Physics of Food Colloids the principles of colloid science will applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food. |      |      |       |                 |
| Objective     | The aggregation of food materials determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production. |      |      |       |                 |
| Content       | Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products. |      |      |       |                 |
| Literature    | Notes will be handed out during the lectures.                |      |      |       |                 |

| 752-3021-00L  | Food Process Design and Optimization                        | W+   | 4    | 2G    | E. J. Windhab  |
| Objective     | Quantitative process analysis and derivation of process-structure functions for complex liquid or semi-liquid food systems with non-Newtonian flow properties. Handling of optimisation and up-/down-scaling procedures. |      |      |       |                 |
| Content       | S-PRO2 scheme, reverse engineering approach, dimension analysis, Metzner-Otto and Riegler Novack design schemes of stirred reactors for non-Newtonian fluid processing, mixing/mixing statistics, mixing characteristics, power charac-teristics, dispersing characteristics, dispersing processes in rotor/ stator and membrane devices, spray processing, extrusion processing, diverse case studies for design and scaling of processes for food structure processing |      |      |       |                 |
| Literature    | Printed handouts (ca. 180)                                  |      |      |       |                 |

| 752-3023-00L  | Process Measurements and Automation                         | W+   | 3    | 2G    | E. J. Windhab  |
| Abstract      | Overview on Process Automation, Information Management in processes, process data handling and analysis, In-line measurements of complex food systems, Process control schemes, Overview of sensors and sensor principles, integrated process control case studies |      |      |       |                 |
| Objective     | Understanding the interplay of in-line measurements of complex food properties in processes, process data handling and data analysis as well as building blocks for process control. |      |      |       |                 |
| Content       | Overview Process Automation, Process Control and process data management, Industrial design of automated/controlled processes, overview on sensors/sensor principles, case studies of in-line measurements and control in/of food production processes |      |      |       |                 |
| Literature    | Printed script (120 pages, 80 figures), diverse publications |      |      |       |                 |

| 752-3201-00L  | Emerging Thermal and Non Thermal Food Processing            | W    | 3    | 2V    | A. Mathys      |
| Abstract      | This course is built on the holistic approach in sustainable food processing via the consideration of the total value chain. Selected mechanical, biotechnological, thermal and non-thermal techniques for best biomass and energy use efficiency will be investigated. Focused technologies are new thermal processes, high pressure techniques, electroporation and different radiation based sources. |      |      |       |                 |
| Objective     | Understanding of selected emerging food processing concepts with focus on lower process intensity for healthy and high quality food production, waste reduction as well as biomass and energy use efficiency. Updates from academia and industry around new trends in food process development |      |      |       |                 |
| Content       | Emerging combined processes based on mechanical, thermal and non-thermal techniques, Multi hurdle technology concept for preservation, Extreme high temperature-short time processes, high pressure techniques, electroporation, radiation, Biorefineries based on emerging process elements, Ongoing industry initiatives |      |      |       |                 |
| Lecture notes | Script will be distributed before the course via Moodle.      |      |      |       |                 |
### Methodology Subjects

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W+</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W+</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
</tbody>
</table>

#### Abstract
- Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

#### Objective
- Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

#### Content
- Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

#### Literature

#### Prerequisites / notice
- The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

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The objective of this course is to highlight the intimate links between human physiology and product sensory and nutritional functions. To achieve this, M. Erzinger assessed Communication, Adaptability and Flexibility.

Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods. M. Schmelcher, M. Devezeaux de Lavergne, S. Michlig Gonzalez, T. Wooster.

Copies of the presentations will be handed out.

Physiology Guided Food Structure and Process Design
Introduction to the principles of the EU and international Organisations, Principles of the Swiss food law. Documents about Codex Alimentarius, the EU regulation as well as the Swiss food law and some regulations will be handed out.

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods. W+

The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics. The students will be exposed to this interplay all along the GI tract, including taste, aroma and texture perception, swallowing mechanics and gastrointestinal digestion with an engineering or physical sciences angle.

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc.) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students. Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

### Methodology Subjects

#### Applied Analysis of Variance and Experimental Design

- **Title**: Applied Analysis of Variance and Experimental Design
- **Type**: W
- **ECTS**: 5
- **Hours**: 2+1U
- **Lecturers**: L. Meier

Prerequisites / notice

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.

#### Statistical Regression

- **Title**: Applied Statistical Regression
- **Type**: W
- **ECTS**: 5
- **Hours**: 2+1U
- **Lecturers**: M. Dettling

Prerequisites / notice

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

Abstract
This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Lecture notes
A script will be available.

Literature
Faraway (2005): Linear Models with R
Faraway (2006): Extending the Linear Model with R
Draper & Smith (1998): Applied Regression Analysis
Fox (2008): Applied Regression Analysis and GLMs
Montgomery et al. (2006): Introduction to Linear Regression Analysis

Prerequisites / notice
The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

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

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

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

ECTS Concepts and Theories 3 credits

W+ 4 credits 2G

N. Bokulich

752-5500-00L "Applied Bioinformatics: Microbiomes"

Abstract
Learn to apply bioinformatics and computational methods for analysis of microbiome next-generation sequencing data. A secondary goal is to critically examine the relevance of microbiomes to food quality, safety, and human health, through application of theory and appropriate experimental design. Students completing this course will thus be able to both apply appropriate methodology to study microbiomes (or other high-dimensional data) in different systems, as well as evaluate and interpret bioinformatics results.

Objective
This course requires extensive engagement in learning outside of the classroom (using online resources and practical exercises), with a focus on active learning in the classroom.

Content
1. Introduction to microbiomes and microbial bioinformatics toolkit. UNIX/bash, Python, Pandas, Jupyter, git/GitHub, visualization libraries for Python.
3. Microbial diversity, function, and ecology. Molecular ecology, diversity metrics, ordination methods.

This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Prerequisites / notice
No specific pre-requisites, but students should have some familiarity with microbiology, molecular biology, programming (UNIX/bash and/or Python), bioinformatics, and statistics.

Students will bring and work on their own laptop computers (students without a laptop should consult with their department’s ISG group).

All software used in the course is free and open-source. Installation instructions will be provided to students prior to the start of the course.

Optional Subjects

<table>
<thead>
<tr>
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<tr>
<td>752-5111-00L</td>
<td>Gene Technology in Foods</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>F. Constancias, G. Broggi, A. Greppi, F. Orelli</td>
</tr>
</tbody>
</table>

Abstract
This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Objective
This course will provide knowledge and biological background on genetically modified organisms (GMO) and food produced with the help of GMO, especially on the molecular basis of GMO constructions with emphasis on genetically modified food in Switzerland and the EU. Criteria of rationale food safety and health assessment in agriculture and food consumption will be elaborated.
Content
Overview on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used
transgenes in food as well as on GMO used for food production and their detection technologies in food; food safety assessment of GMO
food; information on the legislation in Switzerland and EU-countries

Lecture notes
Copies of slides from lectures will be provided

Literature
Actual publications from literature will be provided

Prerequisites / notice
Good knowledge in biology, especially in microbiology and molecular biology are prerequisites.
Some contents will be provided by registered students who will present as a group an actual publication.

752-1300-00L Advanced Topics in Toxicology
Only for students who have previously taken "Special Topics in Food Toxicology" (752-1301-00L).

Abstract
Journal-club style course that involves student presentations of selected topics in Toxicology on the basis of current primary research and
review papers.

Objective
The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and
Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral
presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.

Content
The journal-club style course involves student presentations of recent publications. The primary focus is on chemical and biochemical
aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e.
Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry are prerequisite. Selected course
topics change every semester.

Prerequisites / notice
Participants are required to have completed previously "Special Topics in Toxicology" (752-1301-00L). Both courses are run concurrently
every semester. It is only possible to register for one course at a time. Do not register for "Advanced Topics in Toxicology" until after you
have completed "Special Topics in Toxicology"

376-1353-00L Nanostructured Materials Safety

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin
and intravenous injection

Objective
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide
knowledge to design safer materials

Lecture notes
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course
website

Prerequisites / notice
course "Introduction to Toxicology"

Major in Nutrition and Health

Disciplinary Subjects

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
752-2307-00L Nutritional Aspects of Food Composition and Processing | W+ | 3 credits | 2V | B. E. Baumer, J. M. Sych

Abstract
Lecture type course with an interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to
processing.

Objective
Students should be able to
- describe and compare the major concepts/criteria used for the evaluation of the nutritional quality of food
- apply these criteria when assessing the effects of selected processing technologies on nutritional quality.
- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional
foods).

Content
The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, emerging
technologies) or new formulation strategies. Possible evaluation methods for these changes (e.g. nutritional profile) will be addressed.

Lecture notes
There is no script. Powerpoint presentations and relevant scientific articles will be available on-line for students. A selection of
recommended readings will be given at the beginning of the course.

Prerequisites / notice
The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and
nutrition is expected, as well as an understanding of food processing.

752-6101-00L Dietary Etiologies of Chronic Disease

Abstract
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including
diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic
disease, as well as the progression of complications of the chronic diseases.

Content
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes,
gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes
There is no script. Powerpoint presentations will be made available on-line to students.

Prerequisites / notice
To be provided by the individual lecturers, at their discretion.

752-6105-00L Epidemiology and Prevention

Abstract
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to
the development and evaluation of preventive and treatment interventions and to improved population health.

Objective
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and
public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Content
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection
of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We
will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from
nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.
The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Prerequisites

- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management
  - Communication

- Domain B - Method-specific Competencies
  - Techniques and Technologies
  - Media and Digital Technologies
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- Domain C - Social Competencies
  - Cooperation and Teamwork
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection

- Domain D - Personal Competencies
  - Adaptable and Flexible
  - Critical Thinking
  - Self-direction and Self-management
The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy. To understand the potential effects of nutrition on exercise performance, with a focus on concepts and principles of nutrition before, during, and after exercise.

Lectures

Nutrition-Related Physiology

This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

Objective

To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

Content

This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- Legal and protection issues related to functional foods
- Industrial biotechnology of flavor and taste development
- Safety of food cultures and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

Lecture notes

Copy of the power point slides from lectures will be provided.

Literature

A list of topics for group projects will be supplied, with key references for each topic.

Prerequisites / notice

This lecture requires strong basics in microbiology.

752-6301-00L Nutrition-Related Physiology

Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relationship to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.

Objective

Some basic knowledge in physiology is recommended for this course, which revisits important physiological topics, emphasizing their relationship to nutrition. The aim is to give the students background knowledge necessary for a basic understanding of the complex relationships between food composition and nutrition on one hand and the functioning, as well as the malfunctioning, of major organ systems on the other hand.

Content

The course introduces basic concepts of the interaction between nutrition and exercise performance.

Objective

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Content

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

Lecture notes

Lecture slides and required handouts will be available on the ETH website (moodle).

Literature

Information on further reading will be announced during the lecture. There will be some mandatory as well as voluntary readings.

Prerequisites / notice

General knowledge about nutrition, human biology, physiology and biochemistry is a prerequisite for this course. The course builds on previously acquired knowledge. Major topics are basic neuroanatomy and neurophysiology; general endocrinology; the physiology of taste and smell; nutrient digestion and absorption; intermediary metabolism and energy homeostasis; and some aspects of cardiovascular physiology and water balance.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

752-6111-00L Gene Technology in Foods

This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Abstract

This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Number Type ECTS Hours Lecturers
752-5103-00L Functional Microorganisms in Foods W 3 credits 2G C. Lacroix, A. Geirnaert, A. Greppi
752-6403-00L Nutrition and Performance W+ 2 credits 2V S. Mettler, M. B. Zimmermann
752-5111-00L Gene Technology in Foods W 3 credits 2V F. Constancias, G. Broggi, A. Greppi, F. Orelli

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In this practical course, different meals are prepared and then analysed for nutritional content in the laboratory. The analyses comprise:

- energy, macronutrients and specific micronutrients, as well as polyphenols and phytic acid. Based on these results, the nutritional value of each meal is critically evaluated and discussed. The nutritional values of the meals are discussed, as well as their relation to specific chronic diseases and iron bioavailability. Discussion is facilitated by an oral presentation with colloquium and a written report.

The cooking and laboratory methods will be described in the "script" which will be made available before the start of the course. All lectures will have full notes and a recording made available via Moodle. The practical course Nutrient Analysis in Foods includes meal preparation (a half day between 6 and 10th December 2021, date to be assessed) and chemical analysis of five meals from 5 different types of diets (students will work in groups; one meal per group). The content of macronutrients, specific micronutrients and secondary plant components (polyphenols and phytic acid) are analysed using common analytical methods. The analytical results are compared with calculated data from food composition databases using the nutrition software EbisPro and then critically evaluated.

Performance will be assessed by means of:

1) Contribution to laboratory practical work;
2) A written test on course content (via Moodle, completed by 11.02.2022);
3) A 15 min oral presentation of laboratory results in a seminar with colloquium (active discussion) (on 18.02.2022, afternoon);
4) A 5-page written report per group (deadline 25.02.2022).

For Masters level participants, a strict prerequisite is a previously taken and passed "Introduction to Toxicology" (752-1300) and/or previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.

If you would like to take "Special Topics in Toxicology", do not register at the same time for “Advanced Topics in Toxicology”. It is only possible to take one, and it is only possible to take the advanced level after completing this course.

### Major in Human Health, Nutrition and Environment

#### Module

#### Module Public Health

The course is open to Masters or PhD level students.

For Masters level participants, a strict prerequisite is (a) previously taken and passed "Introduction to Toxicology" (752-1300) and/or (b) previous courses supporting equivalent knowledge plus permission from the instructor. Please contact the instructor before the start of the class, explaining the basis of your previous knowledge other than the Introduction course, to request special permission.

If you would like to take "Special Topics in Toxicology", do not register at the same time for “Advanced Topics in Toxicology”. It is only possible to take one, and it is only possible to take the advanced level after completing this course.
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

Objective

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

Content

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

Prerequisites / notice

The statistical software R will be used in the exercises. If you are unfamiliar with R, it is highly recommend to view the online R course "etutoR".

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1703-00L</td>
<td>Evolutionary Medicine for Infectious Diseases</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Hall</td>
</tr>
<tr>
<td>701-1471-00L</td>
<td>Ecological Parasitology</td>
<td>W</td>
<td>3</td>
<td>1V+1P</td>
<td>J. Jokela, C. Vorburger</td>
</tr>
</tbody>
</table>
Waiting list will be deleted on October 1st, 2021.

Abstract
Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.

Objective
1. Identify common macroparasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

Content
Lectures:
1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
2. Adaptations of parasites (e.g. evolution of life-cycles, host manipulation).
3. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
4. Ecology and evolution of parasitoids and their applications in biocontrol
5. Human macroparasites (schistosomiasis, malaria).

Practical exercises:
1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).
2. Examination of parasites in amphipods (identification and examination of effects on hosts).
3. Examination of parasitoids of aphids.

Prerequisites / notice
The three practicallys will take place at the 05.10.2021, the 19.10.2021 and the 09.11.2021 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.


Abstract
This course provides a detailed understanding of
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies

Objective
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naïve B cells to antibody producing plasma cells and memory B cells.
- Optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT), and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the "Danger" concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at:
https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notifyeditingon=1

Prerequisites / notice
Immunology I and II recommended but not compulsory

752-4009-00L Molecular Biology of Foodborne Pathogens W 3 credits 2V M. Loessner, M. Schmelcher, M. Schuppler, E. Wetter Slack

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
- Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break !

701-0263-01L Seminar in Evolutionary Ecology of Infectious Diseases W 3 credits 2G R. R. Regös, S. Bonhoeffer

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

Objective
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific literature and trace the development of ideas related to understanding the ecology and evolutionary biology of infectious diseases. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.

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

Lecture notes
Publications and class notes can be downloaded from a web page announced during the lecture.

Literature
Papers will be assigned and downloaded from a web page announced during the lecture.
Dietary Etiologies of Chronic Disease  
**W** 3 credits  2V  M. B. Zimmermann

**Abstract**
To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Objective**
To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

**Content**
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Lecture notes**
There is no script. Powerpoint presentations will be made available on-line to students.

**Literature**
To be provided by the individual lecturers, at their discretion.

**Prerequisites / notice**
No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

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Food and Consumer Behaviour  
**W** 2 credits  2V  M. Siegrist, C. Hartmann

**Abstract**
This course focuses on food consumer behaviour, consumer's decision-making processes and consumer's attitudes towards food products.

**Objective**
The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues.

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Functional Microorganisms in Foods  
**W** 3 credits  2G  C. Lacroix, A. Geirnaert, A. Greppi

**Abstract**
This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

**Objective**
To understand the roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

**Content**
This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- Legal and protection issues related to functional foods
- Industrial biotechnology of flavor and taste development
- Safety of foods and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

**Lecture notes**
Copy of the power point slides from lectures will be provided.

**Literature**
A list of topics for group projects will be supplied, with key references for each topic.

**Prerequisites / notice**
This lecture requires strong basics in microbiology.

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Module Environment and Health

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1341-00L</td>
<td>Water Resources and Drinking Water</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Hug, M. Berg, F. Hammes, U. von Gunten</td>
</tr>
</tbody>
</table>

**Abstract**
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

**Objective**
The goal of this lecture is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

**Content**
The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

**Lecture notes**
Handouts will be distributed

**Literature**
Will be mentioned in handouts

| 376-1353-00L | Nanostructured Materials Safety | W     | 2     | 1V    | P. Wick                       |

**Abstract**
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

**Objective**
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

**Lecture notes**
Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website

**Prerequisites / notice**
course "Introduction to Toxicology"

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Term Paper

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<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

Only for students of the Major Human Health, Nutrition and Environment.
Abstract
Writing of a review paper of scientific quality on a topic in the domain of Human Health, Nutrition and Environment based on critical evaluation of scientific literature.

Objective
- Acquisition of knowledge in the field of the review paper
- Assessment of original literature as well as synthesis and analysis of the findings
- Practising of academic writing in English
- Giving an oral presentation with discussion on the topic of the review paper

Content
Topics are offered in the domains of the major 'Human Health, Nutrition and Environment' covering 'Public Health', 'Infectious Diseases', 'Nutrition and Health' and 'Environment and Health'.

Lecture notes
Guidelines will be handed out in the beginning.

Literature
Literature will be identified based on the topic chosen.

★★ Methodology Subjects
The courses are offered in the spring semester

★★ Minors
★★ Food Biotechnology

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<tr>
<th>Number</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>752-5105-00L</td>
<td>Biotechnology of Alcoholic Beverage Production</td>
<td>W+</td>
<td>2</td>
<td>2V</td>
<td>R. Mira de Orduna Heidinger, A. Bühlmann, S. Schönemberg</td>
</tr>
</tbody>
</table>

Abstract
This course introduces fundamental aspects of the production of beer and grape wine.

Objective
The objective of the course is to provide participating students with a sound understanding of the raw materials, microorganisms, microbial and chemical transformations and processing aspects involved in the production of beer and grape wine. Sensory aspects and product stability will also be considered.

Content
>> Introduction of alcoholic beverage production within industrial microbiology
>> Brewing
- Raw materials, and malting
- Brewhouse processes, wort production, fermentations, lagering
- Sensory aspects and diacetyl management
>> Winemaking
- Grapegrowing and grape processing
- Crush and pressing
- Fermentations and microbial transformations
- Fining, stabilizations, filtration and bottling
- Aroma and macromolecule chemistry, climate change
- Sensory aspects and wine faults

Lecture notes
Lecture handouts will be provided either electronically or at the beginning of lectures.

Literature
A list of learning materials will be provided with the lecture handouts.

Prerequisites / notice
Students taking 752-5105-00L require a sound knowledge of basic chemistry, biochemistry, molecular genetics, microbiology and microbial physiology.

In order to decipher the costs of tastings, a financial participation of CHF30 will be required per student.

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<tbody>
<tr>
<td>752-5111-00L</td>
<td>Gene Technology in Foods</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>F. Constancias, G. Broggini, A. Greppi, F. Orelli</td>
</tr>
</tbody>
</table>

Abstract
This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Objective
This course will provide knowledge and biological background on genetically modified organisms (GMO) and food produced with the help of GMO, especially on the molecular basis of GMO constructions with emphasis on genetically modified food in Switzerland and the EU. Criteria of rationale food safety and health assessment in agriculture and food consumption will be elaborated.

Content
Overview on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used transgenes in food as well as on GMO used for food production and their detection technologies in food; food safety assessment of GMO food; information on the legislation in Switzerland and EU-countries

Lecture notes
Copies of slides from lectures will be provided

Literature
Actual publications from literature will be provided

Prerequisites / notice
Good knowledge in biology, especially in microbiology and molecular biology are prerequisites. Some contents will be provided by registered students who will present as a group an actual publication.

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<tr>
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</thead>
<tbody>
<tr>
<td>752-5103-00L</td>
<td>Functional Microorganisms in Foods</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>C. Lacroix, A. Geirnaert, A. Greppi</td>
</tr>
</tbody>
</table>

Abstract
This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

Objective
To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefitting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.
This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

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- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.

- Legal and protection issues related to functional foods

- Industrial biotechnology of flavor and taste development

- Safety of food cultures and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

Lecture notes
Copy of the power point slides from lectures will be provided.

Literature
A list of topics for group projects will be supplied, with key references for each topic.

Prerequisites / notice
This lecture requires strong basics in microbiology.

#### Food Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>752-1021-00L</td>
<td>Food Enzymology</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>L. Nyström, M. Erzinger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The course covers the fundamentals of food enzymology, application of endogenous and exogenous enzymes in food processing, as well as use of enzymes in analytics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students can describe what enzymes are and can explain their use and functions in food and food products. Students can argue why and how enzymes are used in food processing and analysis. Students execute a research project independently and defend their findings during a presentation to peer students and an expert panel.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Enzymes in foods: the use of added enzymes in food processing, control and/or utilization of endogenous enzymes, production of enzyme preparations for food use, and chemical analysis of food components by enzymatic methods.</td>
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<tr>
<td>Lecture notes</td>
<td>The lectures are supplemented with handouts.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Course prerequisites: Food Chemistry I/II and Food Analysis I/II (or equivalent)</td>
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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0041-00L</td>
<td>Modern Mass Spectrometry, Hyphenated Methods, and Chemometrics</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>R. Zenobi, B. Hattendorf, P. Sinués Martinez-Lozano</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Modern mass spectrometry, hyphenated analytical methods, speciation, chemometrics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Comprehensive knowledge about the analytical methods introduced in this course and their practical applications.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Hyphenation of separation with identification methods such as GC-MS, LC-MS, GC-IR, LC-IR, LC-NMR etc.; importance of speciation. Modern mass spectrometry: time-of-flight, orbitrap and ion cyclotron resonance mass spectrometry, ICP-MS. Soft ionization methods, desorption methods, spray methods. Mass spectrometry imaging. Use of statistical and computer-assisted methods for processing analytical data (chemometrics).</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes will be made available online.</td>
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<tr>
<td>Literature</td>
<td>Information about relevant literature will be available in the lecture &amp; in the lecture notes.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Exercises are an integral part of the lecture. Prerequisites: 529-0051-00 &quot;Analytische Chemie I (3. Semester)&quot; 529-0058-00 &quot;Analytische Chemie II (4. Semester)&quot; (or equivalent)</td>
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<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td></td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
<td>not assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>Project Management</td>
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<td></td>
<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<td></td>
<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</table>
Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Literature
Recommendations will be given in the first lecture

Prerequisites / notice
Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

752-5103-00L

Functional Microorganisms in Foods

Abstract
This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

Objective
To understand the principles, rules and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

Content
This course will address selected current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.

- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.

- Legal and protection issues related to functional foods

- Industrial biotechnology of flavor and taste development

- Safety of food cultures and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

Lecture notes
Copy of the power point slides from lectures will be provided.

Literature
A list of topics for group projects will be supplied, with key references for each topic.

Prerequisites / notice
This lecture requires strong basics in microbiology.

Food Process Design

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-3021-00L</td>
<td>Food Process Design and Optimization</td>
<td>W+</td>
<td>4</td>
<td>2G</td>
<td>E. J. Windhab</td>
</tr>
</tbody>
</table>

Abstract

Objective
Quantitative process analysis and derivation of process-structure functions for complex liquid or semi-liquid food systems with non-Newtonian flow properties. Handling of optimisation and up-/down-scaling procedures.

Content
S-PRO2 scheme. reverse engineering approach, dimension analysis, Metzner-Otto and Rieger Novack design schemes of stirred reactors for non-Newtonian fluid processing, mixing/mixing statistics, mixing characteristics, power charac-teristics, dispersing characteristics, dispersing processes in rotor/ stator and membrane devices, spray processing, extrusion processing, diverse case studies for design and scaling of processes for food structure processing.

Lecture notes
Printed handouts (ca. 180)

Literature
List of ca. 30 papers and 5 books given in course.

752-3023-00L

Process Measurements and Automation

Abstract
Overview on Process Automation, Information Management in processes, process data handling and analysis, In-line measurements of complex food systems, Process control schemes, Overview of sensors and sensor principles, integrated process control case studies.

Objective
Understanding the interplay of in-line measurements of complex food properties in processes, process data handling and data analysis as well as building blocks for process control.

Content
Overview Process Automation, Process Control and process data management, Industrial design of automated/controlled processes, overview on sensors/sensor principles, case studies of in-line measurements and control in/of food production processes

Lecture notes
Printed script (120 pages, 80 figures), diverse publications

Literature
List of publications and books given in course.

Food Sensory Science and Consumer Behaviour

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-2122-00L</td>
<td>Food and Consumer Behaviour</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Siegrist, C. Hartmann</td>
</tr>
</tbody>
</table>

Abstract
This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.

Objective
The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues.

Public Nutrition and Health
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health. The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues. Students should be able to - describe and compare the major concepts /criteria used for the evaluation of the nutritional quality of food - apply these criteria when assessing the effects of selected processing technologies on nutritional quality. Lecture type course with an interdisciplinary approach for the evaluation of nutritional aspects of changes in food composition due to processing. The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

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752-5111-00L Gene Technology in Foods  
**Overview** on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

**Abstract**  
This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

**Objective**  
This course will provide knowledge and biological background on genetically modified organisms (GMO) and food produced with the help of GMO, especially on the molecular basis of GMO constructions with emphasis on genetically modified food in Switzerland and the EU. Criteria of rational food safety and health assessment in agriculture and food consumption will be elaborated.

**Content**  
Overview on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used transgenes in food as well as on GMO used for food production and their detection technologies in food; food safety assessment of GMO food; information on the legislation in Switzerland and EU-countries.

**Lecture notes**  
Copies of slides from lectures will be provided.

**Literature**  
Actual publications from literature will be provided.

**Prerequisites / notice**  
Good knowledge in biology, especially in microbiology and molecular biology are prerequisites. Some contents will be provided by registered students who will present as a group an actual publication.

751-7310-00L Bioactive Food and Feed Components  
**Abstract**  
The course provides students with the basic knowledge to understand the connection between the structure of nutritive and non-nutritive bioactive food and feed components and their effects on the nutrient supply and health of humans and livestock as well as on the quality of animal-derived foods.

**Objective**  
At the end of this course, the students are aware of food and feed as sources of different bioactive compounds. By a comprehensive understanding of the connection between bioavailability, molecular mechanisms and biological effects, they are able to apply their knowledge on beneficial and detrimental effects of bioactive food and feed components in the fields of human and animal nutrition.

**Content**  
The course gives an introduction into different classes of bioactive components present in food and feed including fatty acids and secondary plant compounds such as carotenoids, polyphenols, phytoestrogens, glucosinolates, protease inhibitors and monoterpenes.

**Topics include:**  
- sources of bioactive food and feed components  
- bioavailability and modification in the gastrointestinal tract  
- beneficial and detrimental effects  
- molecular mechanisms of biological effects  
- species differences concerning metabolism and biological effects

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

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

### Food Physics

**Number**  
752-3103-00L Food Rheology I

**Content**  
The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

**Objective**  
The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.

**Content**  
Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

**Lecture notes**  
Notes will be handed out during the lectures.

**Literature**  
Provided in the lecture notes.

**Number**  
752-2314-00L Physics of Food Colloids

**Abstract**  
In Physics of Food Colloids the principles of colloid science will applied to the aggregation of food materials based on proteins, polysaccharides, and emulsifiers. Mixtures of such raw material determine the appearance and performance of our daily food. In a number of examples, colloidal laws are linked to food science and the manufacturing and processing of food.

**Objective**  
The aggregation of food material determines the appearance and performance of complex food system as well as nutritional aspects. The underlying colloidal laws reflect the structure of the individual raw material (length scale, time scale, and interacting forces). Once these concepts are appreciated the aggregation of most food systems falls into recognizable patterns that can be used to modify and structure exiting food or to design new products. The application and use of these concepts are discussed in light of common food production.

**Content**  
Lectures include interfacial tension (4h), protein aggregation in bulk and interfaces (4h), Pickering emulsions (2h), gels (2h), aggregation of complex mixtures (4h), and the use of light scattering in investigation complex food structures (8h). Most chapters include some hand-ons examples of the gain knowledge to common food products.

**Lecture notes**  
Notes will be handed out during the lectures.

**Literature**  
Provided in the lecture notes.

### Food Toxicology

**Number**  
752-1301-00L Special Topics in Toxicology

**Abstract**  
Journal-club style course involving student presentations and active discussion and critique of recent publications and modern experimental strategies. The focus is on chemical, biochemical, and nutritional aspects of selected topics in Toxicology, with a new group of topics addressed each semester.

**Objective**  
- to stimulate student interest and provide advanced knowledge of current research in Toxicology and its related sciences  
- to develop skills in critical evaluation of scientific literature, oral presentation and questioning  
- to understand modern experimental techniques and research approaches relevant in Toxicology

**Content**  
The journal-club style course involves student presentations and active discussion of recent publications. The primary focus is on chemical, biochemical, and nutritional aspects of selected current topics in Toxicology. Participants are masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Biochemistry, Pharmaceutical Sciences, etc.).

**Literature**  
A selection of approximately 20 papers from recent primary scientific literature.
The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.

### Content
The journal-style course involves student presentations of recent publications. The primary focus is on chemical and biochemical aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry are prerequisite. Selected course topics change every semester.

**Prerequisites / notice**
Participants are required to have completed previously “Special Topics in Toxicology” (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for “Advanced Topics in Toxicology” until after you have completed “Special Topics in Toxicology”

<table>
<thead>
<tr>
<th>752-1302-00L</th>
<th>Advanced Topics in Toxicology</th>
<th>W</th>
<th>2 credits</th>
<th>2G</th>
<th>S. Huber, S. J. Sturla</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Journal-club style course that involves student presentations of selected topics in Toxicology on the basis of current primary research and review papers.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The goals are to stimulate student interest and provide advanced knowledge of current research in the interdisciplinary area of Food and Nutrition Toxicology and its related sciences. The student should develop skills in the critical evaluation of scientific literature, oral presentation and questioning, and understanding modern experimental techniques in Molecular Toxicology.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The journal-style course involves student presentations of recent publications. The primary focus is on chemical and biochemical aspects of selected topics in Toxicology. Participants are generally masters or PhD students in Food Sciences and related disciplines (i.e. Chemistry, Pharmaceutical Sciences, etc.), and strong knowledge of organic chemistry and biochemistry are prerequisite. Selected course topics change every semester.</td>
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### 752-4009-00L Molecular Biology of Foodborne Pathogens

**Objective**

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Content

Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

**Lecture notes**

Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

**Literature**

Recommendations will be given in the first lecture

**Prerequisites / notice**

Participants are required to have completed previously “Special Topics in Toxicology” (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for “Advanced Topics in Toxicology” until after you have completed “Special Topics in Toxicology”

<table>
<thead>
<tr>
<th>752-4009-00L</th>
<th>Molecular Biology of Foodborne Pathogens</th>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>M. Loessner, M. Schmelcher, M. Schuppler, E. Wetter-Slack</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.</td>
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<td><strong>Objective</strong></td>
<td>The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.</td>
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<tr>
<td><strong>Literature</strong></td>
<td>Recommendations will be given in the first lecture</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Participants are required to have completed previously “Special Topics in Toxicology” (752-1301-00L). Both courses are run concurrently every semester. It is only possible to register for one course at a time. Do not register for “Advanced Topics in Toxicology” until after you have completed “Special Topics in Toxicology”</td>
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### 752-6105-00L Epidemiology and Prevention

**Objective**

The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Content**

The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

**Taught competencies**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
- **Domain B - Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- **Domain C - Social Competencies**
  - Project Management
  - Communication
  - Cooperation and Teamwork
- **Domain D - Personal Competencies**
  - Creative Thinking
  - Critical Thinking

### 376-1353-00L Nanostructured Materials Safety

**Objective**

Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials.

**Prerequisites / notice**

Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.

<table>
<thead>
<tr>
<th>376-1353-00L</th>
<th>Nanostructured Materials Safety</th>
<th>W</th>
<th>2 credits</th>
<th>1V</th>
<th>P. Wick</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course website.</td>
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### Electives

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<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-0005-00L</td>
<td>Colloquium in Food and Nutrition Science</td>
<td>W</td>
<td>1 credit</td>
<td>2K</td>
<td>S. J. Sturla</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Participation in weekly seminars on a variety of topics including Food Microbiology, Food Toxicology, Food Biochemistry, Food Processing, Consumer Behavior, Food Technology, and Food Materials and Technology, and oral presentation of a selected published study in one of these areas inspired by participation in the seminars.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The objectives are to become familiar with and stimulate interest in leading-edge science related to the research topics of the Institute of Food, Nutrition and Health. Participants attend weekly seminars given by external and internal speakers, and are also required to deliver a presentation on a recent research article inspired by a topic from the semester presentations.</td>
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</table>
**Master's Thesis**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-0230-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

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

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme;
c. has acquired at least 30 CPs in the master programme.

The topic of the thesis and - if they are not Professors of D-HEST - the examiner and the co-examiner have to be approved by the D-HEST Department Conference.

Abstract

The Master thesis completes the master programme and is an independent scientific project. Generally, the topic is selected from the specific field of the major. It is supervised by a professor/Privatdozenten at D-HEST or D-USYS, Agricultural Sciences.

Objective

The Master Thesis must demonstrate the student's ability to independent, structured and scientific working.

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**Course Units for Additional Admission Requirements**

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-1000-AAL</td>
<td>Food Chemistry I</td>
<td>E-</td>
<td>3</td>
<td>6R</td>
<td>L. Nyström</td>
</tr>
</tbody>
</table>

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

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

Abstract

To familiarise with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.

Objective

To familiarise with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.

Content

Descriptive chemistry of food constituents (proteins, lipids, carbohydrates, plant phenolics, flavour compounds).

Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (e.g. lipid oxidation, Maillard reaction, enzymatic browning).

Links to food analysis, food processing, and nutrition.

Lecture notes

The lectures are supplemented with handouts.

Literature


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-1101-AAL</td>
<td>Food Analysis I</td>
<td>E-</td>
<td>3</td>
<td>6R</td>
<td>L. Nyström</td>
</tr>
</tbody>
</table>

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

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

Abstract

To understand the basic principles of analytical chemistry. To get acquainted with the principles and applications of important routine methods of instrumental food analysis (UV/VIS, IR, AAS, GC, HPLC).

Objective

To understand the basic principles of analytical chemistry. To get acquainted with the principles and applications of important routine methods of instrumental food analysis (UV/VIS, IR, AAS, GC, HPLC).

Content


Methods: Optical spectroscopy (basic principles, UV/VIS, IR, and atomic absorption spectroscopy). Chromatography (GC, HPLC).

Lecture notes

The lectures are supplemented with handouts.

Literature


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-3000-AAL</td>
<td>Food Process Engineering I</td>
<td>E-</td>
<td>4</td>
<td>9R</td>
<td>P. A. Fischer</td>
</tr>
</tbody>
</table>

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

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

Abstract

To procure students with the basic physics of food process engineering, especially with the mechanical futures of food systems, i.e. basic principles of engineering mechanics, of thermodynamics, fluid dynamics and of dimension analyses for process design and Non-Newtonian fluid mechanics.

Objective


Content


Literature


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>752-6001-AAL</td>
<td>Introduction to Nutritional Science</td>
<td>E-</td>
<td>3</td>
<td>6R</td>
<td>M. B. Zimmermann, C. Wolfrum</td>
</tr>
</tbody>
</table>

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

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

Abstract

This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

Objective

To introduce the students to the both macro- and micronutrients in relation to food and metabolism.

**Lecture notes**

A reading list will be provided to the students detailing chapters and lecture slides to be studied.

**Literature**


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**551-0001-AAL**

**General Biology I**

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

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

**Abstract**

Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

**Objective**

The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

**Content**

Week 1-7 by Alex Widmer, Chapters 12-25

12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34

26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

**Lecture notes**

No script

**Literature**


**Prerequisites / notice**

This is a virtual self-study lecture for non-german speakers of the "Allgemeine Biology I (551-0001-00L) lecture. The exam will be written jointly with the participants of this lecture.

Example exam questions will be discussed during the lectures, and old exam questions are kept by the various student organisations. If necessary, please contact Prof. Uwe Sauer (sauer@ethz.ch) for details regarding the exam.

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**406-0063-AAL**

**Physics II**

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

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

**Abstract**

Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

**Objective**

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

The student should acquire an overview over the basic concepts used in the theory of heat and electricity.

**Content**

Book:


Chapters:


**Literature**

Friedhelm Kuypers
Physik für Ingenieure und Naturwissenschaftler
Band 2 Elektrizität, Optik, Wellen
Verlag Wiley-VCH, 2003, Fr. 77.-

---

**406-0603-AAL**

**Stochastics (Probability and Statistics)**

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

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

**Abstract**

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

**Objective**

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

---

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 4: Sampling Distribution of Averages
Ch 5: Normal Distributions
Ch 6: Student's t Distribution
Ch 7: Distributions of Two Variables

From "Introductory Statistics with R" (online)
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: One- and two-sample tests
Ch 5: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435
  From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

752-4001-AAL Microbiology E- 2 credits 4R M. Ackermann
Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Self-study course in microbiology.

Objective
Teaching of basic knowledge in microbiology.

Content
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Literature
This self-study course is based on the book 'Brock, Biology of Microorganisms'.

701-0071-AAL Mathematics III: Systems Analysis E- 4 credits 9R R. Knutti, H. Wernli
Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

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

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

Content
Introduction to principles of models; one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time

Lecture notes
Teaching material: book (see literature).

Literature

752-4005-AAL Food Microbiology I E- 3 credits 6R M. Loessner
Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.
Content
1. History of Food Microbiology
   1.1. Short synopsis of foodborne microorganisms
   1.2. Spoilage of Foods
   1.3. Foodborne Disease
   1.4. Food Preservation
   1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
   2.1. Origin of foodborne Microorganisms
   2.2. Bacteria
   2.3. Yeasts
   2.4. Molds
3. Microbial Spoilage of Foods
   3.1. Intrinsic and Extrinsic Parameters
   3.2. Meats, Seafoods, Eggs
   3.3. Milk and Milk Products
   3.4. Vegetable and Fruit Products
   3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
   3.6. Drinks and Canned Foods
4. Foodborne Disease
   4.1. Significance and Transmission of Foodborne pathogens
   4.2. Staphylococcus aureus
   4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
   4.4. Listeria monocytogenes
   4.5. Salmonella, Shigella, Escherichia coli
   4.6. Vibrio, Yersinia, Campylobacter
   4.7. Brucella, Mycobacterium
   4.8. Parasites
   4.9. Viruses and Bacteriophages
   4.10. Mycotoxins
   4.11. Bioactive Amines
   4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

551-0003-AAL General Biology I+II E- 7 credits 13R U. Sauer, K. Bomblies, O. Y. Martin, A. Widmer
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

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

Abstract
General Biology I: Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.
General Biology II: Molecular biology approach to teach the basic principles of biochemistry, cell biology, cgenetics, evolutionary biology and form and function of vascular plants.

Objective
General Biology I: The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.
General Biology II: The understanding basic concepts of biology: the hierarchy of the structural levels of biological organisation, with particular emphasis on the cell and its molecular functions, the fundamentals of metabolism and molecular genetics, as well as form and function of vascular plants.
Content

General Biology I:
General Biology I focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

General Biology II: The structure and function of biomacromolecules; basics of metabolism; tour of the cell; membrane structure and function; basic energetics of cellular processes; respiration, photosynthesis; cell cycle, from gene to protein; structure and growth of vascular plants, resource acquisition and transport, soil and plant nutrition.

Specifically the following Campbell chapters will be covered:
3 Biochemistry Chemistry of water
4 Biochemistry Carbon: the basis of molecular diversity
5 Biochemistry Biological macromolecules and lipids
7 Cell biology Cell structure and function
8 Cell biology Cell membranes
10 Cell biology Respiration: introduction to metabolism
10 Cell biology Cell respiration
11 Cell biology Photosynthetic processes
16 Genetics Nucleic acids and inheritance
17 Genetics Expression of genes
18 Genetics Control of gene expression
19 Genetics DNA Technology
35 Plant structure & function Plant Structure and Growth
36 Plant structure & function Transport in vascular plants
37 Plant structure & function Plant nutrition
38 Plant structure & function Reproduction of flowering plants
39 Plant structure & function Plants signal and behavior

Lecture notes
No script

Literature

Prerequisites / notice
Basic general and organic chemistry

This is a virtual self-study lecture for non-German speakers of the “Allgemeine Biology I (551-0001-00L) and “Allgemeine Biology II (551-0002-00L) lectures. The exam will be written jointly with the participants of this lecture.

752-0100-AAAL

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

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

Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo.

Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

Objective
Based on the biology and chemistry courses in the 1. and 2. semester more detailed biochemical knowledge about enzymology, membrane biochemistry, and central metabolism will be presented

Content
Program
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Carbohydrates, structure of DNA
Lipids and biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis
The citric acid cycle
Oxidative phosphorylation
Fatty acid metabolism

Lecture notes
textbook
by Lawrence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Literature
textbook
by Lawrence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Prerequisites / notice
Basic knowledge in biology and chemistry is a precondition.
Taught competencies

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

Domain B - Method-specific Competencies
- Analytical Competencies: not assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Leadership and Responsibility: not assessed
- Negotiation: not assessed

752-6306-AAL  Physiology and Anatomy II  E-  3 credits  6R  D. Burdakov, M. Ristow

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Imparts a basic understanding of physiology and anatomy in man, focusing on the close interrelations between morphology and function of the human organism. This is fostered by discussing all subjects from a functional point of view. A major topic of the lecture is food intake and digestion with its correlated endocrine and metabolic processes.

Objective
After this course the students are able to understand basic principles of systems physiology and the mechanisms of the function of the major organ systems.

Food Science Master - Key for Type

| O | Compulsory
| W+ | Eligible for credits and recommended
| W | Eligible for credits

| E- | Recommended, not eligible for credits
| Z | Courses outside the curriculum
| Dr | Suitable for doctorate

Key for Hours

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

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

ECTS  European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
## First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>529-2001-02L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>J. Cvengros, J. E. E. Buschmann, P. Funck, E. C. Meister, R. Verel</td>
</tr>
<tr>
<td>401-0251-00L</td>
<td>Mathematics I</td>
<td>O</td>
<td>6</td>
<td>4V+2U</td>
<td>F. Da Lio</td>
</tr>
</tbody>
</table>

### Abstract

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

### Objective

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

### Content

1. **Stoichiometry**
   - Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.

2. **Atoms**

3. **Chemical bonding and its representation.**
   - Spatial arrangement of atoms in molecules. Molecular orbitals.

4. **Basics of chemical thermodynamics.**
   - System and surroundings. Description of state and change of state of chemical systems.

5. **First law of thermodynamics**

6. **Second law of thermodynamics**
   - Entropy. Change of entropy in chemical systems and universe. Reaction entropy.

7. **Gibbs energy and chemical potential.**

8. **Chemical equilibrium**

9. **Acids and bases**

10. **Dissolution and precipitation.**
    - Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.

### Taught competencies

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

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibilty: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

### Literature

- **Online-Skript mit durchgerechneten Beispielen.**
- **Weiterführende Literatur:**
  - Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)
Content

1. Single-Variable Calculus:
   review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

2. Linear Algebra and Complex Numbers:
   systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.

3. Ordinary Differential Equations:
   separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

Literature

- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).

Prerequisites / notice

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

<table>
<thead>
<tr>
<th>551-0001-00L</th>
<th>General Biology I</th>
<th>O</th>
<th>3 credits</th>
<th>3V</th>
<th>U. Sauer, O. Y. Martin, A. Widmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny. First in a series of two lectures given over two semesters for students of agricultural and food sciences, as well as of environmental sciences.</td>
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<tr>
<td>Objective</td>
<td>The understanding of some basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.</td>
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<tr>
<td>Content</td>
<td>The first semester focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.</td>
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<table>
<thead>
<tr>
<th>701-0243-01L</th>
<th>Biology III: Essentials of Ecology</th>
<th>O</th>
<th>3 credits</th>
<th>2V</th>
<th>C. Buser Moser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified by using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. Threats to biodiversity and the appropriate management are discussed.</td>
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<tr>
<td>Objective</td>
<td>The objective of this lecture is to teach basic ecological concepts and the different levels of complexity in ecological research. The students should learn ecological concepts at these different levels in the context of concrete examples from terrestrial and aquatic ecology. Corresponding methods for studying the systems will be presented. A further aim of the lecture is that students achieve an understanding of biodiversity, why it is threatened and how it can be managed.</td>
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<tr>
<td>Content</td>
<td>- Einfluss von Umweltfaktoren (Temperatur, Strahlung, Wasser, Nährstoffe etc.) auf Organismen; Anpassung an bestimmte Umweltbedingungen</td>
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<td></td>
<td>- Populationsdynamik: Ursachen, Beschreibung, Vorhersagen und Regulation</td>
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<td></td>
<td>- Interaktionen zwischen Arten (Konkurrenz, Koexistenz, Prädation, Parasitismus, Nahrungsnetze)</td>
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<td></td>
<td>- Lebensgemeinschaften: Struktur, Stabilität, Sukzession</td>
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<td></td>
<td>- Ökosysteme: Kompartimente, Stoff- und Energieflüsse</td>
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<td></td>
<td>- Biodiversität: Variation, Ursachen, Gefährdung und Erhaltung</td>
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<td></td>
<td>- Aktuelle Naturschutzprobleme und -massnahmen</td>
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<tr>
<td></td>
<td>- Evolutionäre Ökologie: Methodik, Spezialisierung, Koevolution</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Unterragen, Vorlesungsfolien und relevante Literatur sind in Moddle abrufbar. Die Unterragen für die nächste Vorlesung stehen jeweils spätestens am Freitagmorgen zur Verfügung.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>701-0001-00L</th>
<th>Environmental Systems I</th>
<th>O</th>
<th>2 credits</th>
<th>2V</th>
<th>C. Schär, N. Dubois, G. Velicer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The lecture provides a science-based exploration of environmental aspects from three research fields: earth, climate, and health sciences. The students are able to explain important properties of the three environmental systems, to discuss critical drivers, trends and conflicts of their use, and to compare potential solutions.</td>
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</tbody>
</table>

Knowledge about the World Food System will be provided, based on case studies along food value chains in countries with various development stages and dependent on multiple boundary conditions. This shall generate profound understanding of the associated global challenges especially food scarcity, suboptimal diet and nutrition, food quality and safety as well as effects on the environment.

Slides are provided by instructors and are accessible via moodle.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0839-00L</td>
<td>Informatics</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>L. E. Fässler, M. Dahinden</td>
</tr>
</tbody>
</table>

Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists and tables and with relational databases, introduction to programming.

- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

Additional First Year Courses

The course is part of the block exam after the first study year. Paper copies can be used ("Open Book") during the on-line exam, but no other means are not allowed. The course is taught in German.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

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

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

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

Market failure: What happens when prices give wrong signals?

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

National accounts: How big is the Swiss economy?

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

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

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


Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

- Domain A - Subject-specific Competencies
- Domain B - Method-specific Competencies
- Domain D - Personal Competencies

Concepts and Theories assessed
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Critical Thinking assessed
Self-direction and Self-management assessed

Autumn Semester 2021
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to macro programming
5. Introduction to programming with Python

Lecture notes
All materials for the lecture are available at www.evim.ethz.ch

Prerequisites / notice
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

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**751-0801-00L Fundamentals of Microscopy and Plant Biology**

**O** 1 credit 1V+2G E. B. Truernit

**Abstract**

**Objective**
Capability of preparing biological specimen, microscopy and documentation. Understanding the correlation between plant structure and function at the level of organs, tissues and cells. Awareness of the link between plant anatomy, systematics, physiology, ecology, and development.

**Content**

**Lecture notes**
Handouts

**Literature**
For further reading (not obligatory): Gerhard Wanner: Mikroskopisch-Botanisches Praktikum, Georg Thieme Verlag, Stuttgart.

**Prerequisites / notice**
Groups of a maximum of 30 students.

---

**529-0030-00L Laboratory Course: Elementary Chemical Techniques**

**O** 3 credits 6P A. de Mello, F. Jenny, M. H. Schroth

**Abstract**
This practical course provides an introduction to elementary laboratory techniques. The experiments cover a wide range of techniques, including analytical and synthetic techniques (e.g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

**Objective**
This course is intended to provide an overview of experimental chemical methods. The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.

**Content**
The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks: Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvatation or precipitation processes) is studied. The synthesis of simple inorganic complexes or organic molecules is practised. Furthermore, the preparation and handling of environmentally relevant gaseous species like carbon dioxide or nitrogen oxides is a central subject of the Praktikum.

**Lecture notes**
The script will be published on the web. Details will be provided on the first day of the semester.

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

**Prerequisites / notice**
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

---

3. Semester

Basic Courses II

Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0063-00L</td>
<td>Physics II</td>
<td>O</td>
<td>5</td>
<td>3V+1U</td>
<td>A. Vaterlaus</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the concepts and tools in Physics, with the help of demonstration experiments. The Chapters treated are Electromagnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena. Whenever possible, examples relevant to the students’ main field of study are given.

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

**Lecture notes**
A script will be distributed
### 701-0071-00L Mathematics III: Systems Analysis

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

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

**Content**
https://iac.ethz.ch/edu/courses/bachelor/vorbereitung/systemanalyse.html

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

**Literature**


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### 752-4001-00L Microbiology

**Abstract**
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

**Objective**
Teaching of basic knowledge in microbiology.

**Content**

**Lecture notes**
Wird von den jeweiligen Dozenten ausgegeben.

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

---

### 752-0100-00L Biochemistry

**Abstract**
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

**Objective**
Students are able to understand
- the structure and function of biological macromolecules
- the kinetic bases of enzyme reactions
- thermodynamic and mechanistic basics of relevant metabolic processes

Students are able to describe the relevant metabolic reactions in detail

**Content**
Program

Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry

Structure and function of proteins
Carbohydrates
Lipids an biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis, fermentation
The citric acid cycle
Oxidative phosphorylation
Fatty acid metabolism

**Lecture notes**
Horton et al. (Pearson) serves as lecture notes.

**Prerequisites / notice**
Basic knowledge in biology and chemistry is a prerequisite.
Analytical Competencies
J. Ernest assessed

Lecturers assessed Organic Chemistry

Einführung in die Wahrscheinlichkeitsrechnung (Grundregeln, Zufallsvariable, diskrete und stetige Verteilungen, Ausblick auf

Title
K. McNeill not assessed

not assessed

ECTS
2V+1U

4P

2V

Laboratory Course in Physics for Students in Food Sciences
Imparts a basic understanding of physiology and anatomy, focusing on the interrelations between morphology and function of the human

Capacity to learn from data; good practice when dealing with data and recognizing possible fraud in statistics; basic knowledge about the

not assessed

1. Gain an introductory knowledge of the multi-disciplinary topics comprising Food Science.
2. Understand how the multiple disciplines of food science interrelate in an applied context via guided learning of selected examples of foods and human health.
3. Be prepared to make informed decisions about future steps in the food science education and career.
4. Be able to write a well-structured paragraph


Laboratory Course in Physics for Students in Food Sciences
Enrollment is only possible under https://www.lehrbetrieb.ethz.ch/laborpraktika. No registration required via myStudies. For further

Laboratory Course in Physics for Students in Food Sciences
O 2 credits

4P

A. Biland, A. Müller

Additional Courses

Taught competencies

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

Domain B - Method-specific Competencies
Analytical Competencies not assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

752-6305-00L Physiology and Anatomy I

O 2 credits

2V D. Burdakov, D. Peleg-Raibstein

Imparts a basic understanding of physiology and anatomy, focusing on the interrelations between morphology and function of the human organism. This is fostered by discussing all subjects from a functional point of view. One major topic of the lecture is food intake, food taste, and digestion with its correlated neural, endocrine and metabolic processes.

At the end of the course the students understand the basic functions of the organ systems and functionally important morphological features. One focus of the course is on aspects related to nutrition and overweight including the resulting diseases.

701-0225-00L Organic Chemistry

Basics of Organic Chemistry. Reaction mechanisms in organic chemistry (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution and NMR spectroscopy)

This course builds on General Chemistry I and II.

The students will learn the basic reaction mechanisms in organic chemistry. They will be able to understand and formulate simple organic reactions.

Descriptive chemistry of functional groups (alkyl halides, aikenes, aromatic systems, carboxyls). Reaction mechanisms (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution).

Carsten Schmuck, Basisbuch Organische Chemie, Pearson

Der Stoff der Basischemie wird vorausgesetzt.

Exam Block 2

752-0180-00L Principles in Food Science

What is Food Science? The course will introduce students to the biological, physical and engineering basis of food and its role for society. It will center around 3 case examples in which students will be introduced to basic concepts integrating several key disciplines of food science. Each example will be comprised of significant active learning content and practice in scientific communication.

1. Gain an introductory knowledge of the multi-disciplinary topics comprising Food Science.
2. Understand how the multiple disciplines of food science interrelate in an applied context via guided learning of selected examples of foods and human health.
3. Be prepared to make informed decisions about future steps in the food science education and career.
4. Be able to write a well-structured paragraph

Additional Courses

402-0000-02L Laboratory Course in Physics for Students in Food Sciences

Enrollment is only possible under https://www.lehrbetrieb.ethz.ch/laborpraktika. No registration required via myStudies. For further
Only students from 3rd Semester BSc Food Science on are admitted to this Laboratory Course.

Abstract
The central aim is to provide an individual experience of the physical phenomena and the basic principles of the experiment. By conducting simple physical experiments the student will learn how to properly use physical instruments and how to evaluate the results correctly.

Objective
- The setup of a physics experiment,
- the use of measurement instruments,
- various measuring techniques,
- the analysis or measurement errors,
- and the interpretation of the measured quantities.

Content

Deutsch
Die Auswahl der Versuche kann zwischen den verschiedenen Studiengängen variieren.

Lecture notes
Anleitungen zum Physikalischen Praktikum

752-4003-00L Practical Course in Microbiology

Abstract
Basic principles of the handling of microorganisms (MO) - Detection of MO in the environment - Morphology and diagnostics of MO - Morphology and physiology of fungi - Antimicrobial agents - Microbial genetics - Bacterial physiology and interactions - Microbial pest control

Objective
- The students are familiar with the laboratory work with microorganisms. Specific emphasis is put on the isolation and maintenance of pure cultures and the required hygiene measures. The students know the clinical and ecological importance of microorganisms.

Content
In an introductory part students are made familiar with the handling and cultivation of microorganisms (MO). Afterwards, the students detect MO in the environment and use MO for the conservation of food. This part is then followed by a practical introduction on routine diagnostics of MO and experiments with antimicrobial agents. On simple experiments, the students experience the interaction of MO with higher organisms - the common topic of all research groups at the Institute of Microbiology. Some simple experiments demonstrate the importance of MO in molecular genetics. The course ends with a short introduction into the fungi and an example of applied microbiology i.e. an experiment on microbial pest control.

Lecture notes
A detailed script of approx. 100 pp. and other relevant documents are available at Moodle at latest 1 week before the beginning of the practical course.

Literature
Recommended literature (facultative):
- Allgemeine Mikrobiologie by Georg Fuchs and Hans G. Schlegel, Thieme-Verlag, 9. Auflage 2014
- Taschenlehrbuch Biologie: Mikrobiologie by Katharina Munk, Thieme Verlag, 2008

Prerequisites / notice
Performance of the students in this practical course is controlled by:
1. Attendance of all 7 course days
2. Handing in of written reports to selected experiments (in groups of 2 students)
3. Preparation of a poster to a selected topic of Microbiology (in groups of 4 students)

Participating doctoral students who collect credit points during their thesis are examined in a 30-minute oral exam at the end of the course.

Basics of Food Science

Number Title Type ECTS Hours Lecturers
752-1000-00L Food Chemistry I W+ 3 credits 2V L. Nyström, S. Boulos, M. Erzinger
752-5001-00L Food Biotechnology W 4 credits 3V C. Lacroix, F. Constancias, B. Pugin

Basics of Food Science

Number Title Type ECTS Hours Lecturers
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Basics of Food Science

Number Title Type ECTS Hours Lecturers
752-1000-00L Food Chemistry I W+ 3 credits 2V L. Nyström, S. Boulos, M. Erzinger
752-5001-00L Food Biotechnology W 4 credits 3V C. Lacroix, F. Constancias, B. Pugin
Objective
The main goal for this course is to provide students with basic information for understanding biotechnology applied to food processing. For the students, the aim will be:
- To understand the important role of microbial physiology and molecular tools for food biotechnology;
- To understand basic principles of fermentation biotechnology, with particular emphasis on metabolism and kinetics for food applications.

Content
Biotechnology has been defined as any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses. In this course, basic knowledge for understanding biotechnology as applied to food processing will be presented. This course builds on the application of principles learned from other basic courses in the Bachelor program, especially microbiology and microbial metabolism, molecular biology, biochemistry, physics and engineering. Students will learn about the physiology of important productive microorganisms (lactic acid bacteria, bifidobacteria, propionibacteria and fungi) used in food fermentations, closely related to applications in biotechnology. Microbial and fermentation kinetics, and design and operation of fermentations and bioreactors used for both research and industrial scale production of traditional foods and modern food ingredients will be presented. This part will be illustrated by examples of food fermentation processes, representative of specific challenges. Finally, the application of modern molecular tools to food biotechnology will be discussed.

Lecture notes
A copy of the power point slides from each lecture will be provided.

Literature
A list of references will be given at the beginning of the course for the different topics presented during the course.

752-6001-00L
Introduction to Nutritional Science

Abstract
This course introduces basic concepts of micro- and macronutrient nutrition. Macronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

Objective
To introduce the students to the both macro- and micronutrients in relation to food and metabolism.

Content
The course is divided into two parts. The lectures on micronutrients are given by Prof. Zimmermann and the lectures on macronutrients are given by Prof. Wolfrum. Prof. Zimmermann discusses the micronutrients, including fat-soluble vitamins, water-soluble vitamins, minerals and trace elements. Prof. Wolfrum introduces basic nutritional aspects of proteins, fats, carbohydrates and energy metabolism. The nutrients are described in relation to digestion, absorption and metabolism. Special aspects of homeostasis and homeorhesis are emphasized.

Lecture notes
There is no script. Powerpoint presentations will be made available.

Literature
Garrow JS and James WPT: Human Nutrition and Dietetics
Churchill Livingstone, Edinburgh, 11th rev. ed. 2005

752-4005-00L
Food Microbiology I

Abstract
This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective
The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms. The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.

Content
1. History of Food Microbiology
1.1. Short synopsis of foodborne microorganisms
1.2. Spillage of Foods
1.3. Foodborne Disease
1.4. Food Preservation
1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
2.1 Origin of foodborne Microorganisms
2.2. Bacteria
2.3. Yeasts
2.4. Molds
3. Microbial Spoilage of Foods
3.1. Intrinsic and Extrinsic Parameters
3.2. Meats, Seafoods, Eggs
3.3. Milk and Milk Products
3.4. Vegetable and Fruit Products
3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
3.6. Drinks and Canned Foods
4. Foodborne Disease
4.1. Significance and Transmission of Foodborne pathogens
4.2. Staphylococcus aureus
4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
4.4. Listeria monocytogenes
4.5. Salmonella, Shigella, Escherichia coli
4.6. Vibrio, Yersinia, Campylobacter
4.7. Brucella, Mycobacterium
4.8. Parasites
4.9. Viruses and Bacteriophages
4.10. Mycotoxins
4.11. Bioactive Amines
4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Literature
Elmadfa I & Leitzmann C: Ernährung des Menschen
UTB Ulmer, Stuttgart, 4. überarb. Ausgabe 2004

Food Science General Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>551-0317-00L</td>
<td>Immunology I</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>M. Kopf, A. Oxenius</td>
</tr>
</tbody>
</table>

Abstract
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.

Objective
Introduction into structural and functional aspects of the immune system. Basic knowledge of the mechanisms and the regulation of an immune response.
Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histocompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Lecture notes
Electronic access to the documentation will be provided. The link can be found at "Lernmaterialien"

Literature
- Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Taught</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
<td></td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td>not assessed</td>
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<td></td>
<td>Problem-solving</td>
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<td>assessed</td>
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<td></td>
<td>Project Management</td>
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<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Customer Orientation</td>
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<td>not assessed</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
<td>Negotiation</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
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<td>assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

752-2120-00L Consumer Behaviour I

Abstract
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

Objective
Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior

752-1003-00L Food Chemistry II

Abstract
To familiarize with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.

Objective
- Recognize chemical structures of the main ingredients and be able to draw them themselves
- Understand foods as complex systems and be able to make connections between chemical structures, chemical reactions and their influence on quality.
- Recognize chemical reactions of lipid oxidation, Maillard reaction and enzymatic reactions and be able to formulate them themselves.

Content
- Descriptive chemistry of food constituents (proteins, lipids, carbohydrates, plant phenolics, flavour compounds).
- Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (e.g. lipid oxidation, Maillard reaction, enzymatic browning).
- Links to food analysis, food processing, and nutrition.

Topics:
- Lipid oxidation, Maillard reaction, structural proteins/enzymes
- Food as complex systems
- Chemical reactions and reaction mechanisms
- Selected (possibly changing) food chemistry topics (e.g. sweeteners, polysaccharides, from olive to margarine, etc.)

The lectures Food Chemistry I and Food Chemistry II constitute a unit.

Lecture notes
The lectures are supplemented with handouts.

Literature

752-1103-00L Food Analysis II

Abstract
To get acquainted with the principles and applications of mass spectrometry in food analytics.

Objective
To get acquainted with the principles and applications of mass spectrometry in food analytics.

Content
Main focus: Mass spectrometry, applications of mass spectrometry (MS).

Lecture notes
The lectures are supplemented with handouts.

752-3001-00L Food Process Engineering II

Abstract
To procure students with the basics of mechanical process engineering with main focus on mechanical unit operations used in the food industry.

Objective
Training in mechanical unit operations and understanding of the related impact on food structure and properties.

Content
- Darstellung von Partikelgrössenverteilungen, Trennen, Zerkleinern, Agglomerieren, Beschreibung von Hauflwerken, Haftkräfte, Kapillardruckdifferenzen. Sedimentation, Fest Flüssig Trennung
- Es werden Übungen durchgeführt

Lecture notes
Script (ca. 100 pages, 80 figures), Lecturing slides

Literature
- F. Löffler, Grundlagen der mechanischen Verfahrenstechnik
### Food Science Laboratory Practice

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>752-4007-00L</td>
<td>Experimental Food Microbiology</td>
<td>W</td>
<td>3</td>
<td>4P</td>
<td>M. Schuppler</td>
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<td></td>
<td>Number of participants limited to 48.</td>
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<td></td>
<td>Registration only after having attended the course Lebensmittel-Mikrobiologie I (752-4005-00L).</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Teaching of basic experimental knowledge for detection and identification of relevant microorganisms in food. Various practical experiments were accompanied by theoretical introductions to the different topics. The students become acquainted with state-of-the-art methods with main focus on modern molecular techniques for the rapid detection of food borne pathogens.</td>
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<td>Objective</td>
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<td></td>
<td>Teaching of basic experimental knowledge for detection and identification of relevant microorganisms in food.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Grundtechniken für die mikrobiologische Untersuchung von Lebensmitteln, Qualitätssicherung, Anwendung von antimikrobiellen Wirkstoffen, Nachweismethoden für die wichtigsten pathogenen Keime aus Lebensmitteln und einzelnen Keimen aus fermentierten oder probiotischen Lebensmitteln mit klassischen Methoden (u.a. Anreicherungssysteme, ELISA, Enzymsysteme) und Methoden der Molekularbiologie (PCR, Hybridisierung, in-situ-Nachweis), Durchführung von Gentransfermethoden mit Mikroorganismen (Konjugation, Transformation) und Bakteriophagen in Lebensmitteln</td>
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<td></td>
<td>Lecture notes</td>
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<td></td>
<td>Wird am Praktikumanfang abgegeben.</td>
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<td></td>
<td>Literature</td>
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<td></td>
<td>- Krämer: &quot;Lebensmittel-Mikrobiologie&quot; (Ulmer; UTB)</td>
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<td></td>
<td>- Süssmuth et al.: &quot;Mikrobiologisch-Biochemisches Praktikum&quot; (Thieme)</td>
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<td>Prerequisites / notice</td>
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<td></td>
<td>Important information!</td>
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<td></td>
<td>During the course we will work with the food-borne pathogen Listeria monocytogenes. Listeria monocytogenes represents a particular threat in case of pregnancy. Due to biosafety reasons participation is not allowed in case of pregnancy.</td>
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<tr>
<td>752-2002-00L</td>
<td>Food Technology Laboratory Course</td>
<td>W</td>
<td>2</td>
<td>4P</td>
<td>H. Adelmann</td>
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<tr>
<td></td>
<td>Number of participants limited to 55</td>
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<td></td>
<td>Prerequisite: Attendance of the course 752-2001-00L &quot;Food Technology&quot;.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Practical laboratory work on pilot plant scale on important processes for selected foods from the raw material to the final product. Evaluation of food quality.</td>
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<td>Objective</td>
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<td></td>
<td>Know how and handling of the production from selected manufacturing processes to the preservation of food. Understanding the effects of important parameters to the preservation of food including the evaluation of the raw material and the intermediate as well as final products; Analyzing the effects with defined manufacturing processes on the quality of the final products; Evaluation of scientific and non-scientific information and sources.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>This practical course contains different experimental blocks:</td>
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<tr>
<td></td>
<td>- Production of sterile canned goods, determination of sterilization conditions (obligation for all studying)</td>
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<td></td>
<td>- Production of long paste goods (humidification, drying process and Characteristic)</td>
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<td></td>
<td>- Production and processing of meat-loaf (employment of nitrite salts and their effect)</td>
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<td></td>
<td>- Production of potato flakes (Characteristic of the ingredients among other things content of strength and drying process)</td>
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<tr>
<td></td>
<td>- Production of Tofu (from the soy bean to finished Tofu)</td>
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<td></td>
<td>- Hot extruding of corn semolina</td>
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<td></td>
<td>- Characteristic of wheat flour and production of bread (paste preparing/computations and various analyses)</td>
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<td></td>
<td>Lecture notes</td>
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<td>All information and the program will be sent to enrolled students prior to the start of the laboratory course by e-mail. The scripts for this course on the page of the course catalogue in learning materials are available online and can be viewed after login.</td>
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<td></td>
<td>Literature</td>
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<tr>
<td></td>
<td>References are given in the manusscript.</td>
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<td></td>
<td>Prerequisites / notice</td>
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<tr>
<td></td>
<td>Prerequisite is the participation in the course 752-2001-00L Food Technology.</td>
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</table>
Articles and book abstracts will be uploaded to a course website. This course is structured in 3 blocks:

**Block (I): Fundamentals of engineering in biological materials**
- Basic building blocks found in biological materials

**Block (II): Replicating biological design principles in synthetic materials**
- Biological and bio-inspired materials: polymer-reinforced and ceramic-toughened composites
- Lightweight biological and bio-inspired materials
- Functional biological and bio-inspired materials: surfaces, self-healing and adaptive materials

**Block (III): Bio-inspired design and systems**
- Mechanical actuation - plant systems
- Bio-inspiration in the built environment

The course is mainly based on the books listed below. Additional references will be provided during the lectures.

Health expenditures constitute about 10% of GDP in OECD countries. Extensive government intervention is a typical feature in health markets. Risk factors to health have been changing with growing importance of lifestyle factors such as smoking, obesity and lack of physical activity. This course gives an introduction to the economic concepts and empirical findings in health economics.

Objective
Introduce students without prior economic background to the main concepts of health economics and policy to enhance students understanding of how health care institutions and markets function.

Please note that we will apply basic economic concepts to health care markets. Hence, master students with an economic background have to expect that a large share of the concepts will overlap with their previous courses. However, they are, of course, welcome to join the course.

Content
The course gives an introduction to the economic concepts and empirical findings in health economics to enhance students understanding of how health care institutions and markets function. Motivated by the fact that health care markets are designed differently across countries, this course looks at the challenges in regulating health care markets. First, two important decisions of individuals will be analyzed: What types and amount of personal health care services does an individual demand? How much will health insurance coverage be purchased? In the second part, the supply side of health care markets will be discussed. What are the financial incentives of physicians, and how do these influence physicians’ treatment choices? What does it mean and imply that a physician is an agent for a patient? The choices made by societies about how health care services are financed and about the types of organizations that supply health care will be addressed in the third part. One important choice is whether a country will rely on public financing of personal health care services or encourage private health insurance markets. How could and should a public health insurance system be designed? The advantages and disadvantages of the alternatives will be discussed to provide a framework for analyzing specific types of health care systems.

Literature

Prerequisites / notice
Although we apply basic economic concepts to health care questions, students should be aware that this course requires some mathematical skills in terms of maximization problems.

Please be prepared that this course might (partially) be run via zoom, depending on the situation.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Type</th>
<th>Generator</th>
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</thead>
<tbody>
<tr>
<td>363-0387-00L</td>
<td>Corporate Sustainability</td>
<td>3</td>
<td>W</td>
<td>2G</td>
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<tr>
<td>V. Hoffmann, C. Bening-Bach, N. U. Blum, J. Meuer</td>
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<tr>
<td>Abstract</td>
<td>The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food.</td>
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<tr>
<td>Objective</td>
<td>Students</td>
<td>- assess the limits and the potential of corporate sustainability for sustainable development</td>
<td>- develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method.</td>
<td>- recognize and realize opportunities through team work for corporate sustainability in a business environment</td>
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<tr>
<td>Content</td>
<td>In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share their insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.</td>
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<tr>
<td>Lecture notes</td>
<td>Presentation slides will be made available on moodle prior to lectures.</td>
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<tr>
<td>Literature</td>
<td>Literature recommendations will be distributed during the lecture</td>
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<tr>
<td>Prerequisites / notice</td>
<td>TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.</td>
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<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>701-0985-00L</td>
<td>Social Intercourse with Current Environmental Risks</td>
<td>1</td>
<td>W</td>
<td>1V</td>
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<tr>
<td>B. Nowack</td>
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<tr>
<td>Abstract</td>
<td>The lecture treats the social intercourse with risks of technical systems. The notion of risk and the perception of risk are discussed by case studies (e.g. nanotechnology) and socio-political instruments for decision-making are presented. Methods are presented that can be applied to deal with environmental risks and how they can be used for sustainable innovation.</td>
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<tr>
<td>Objective</td>
<td>- Getting acquainted to the extended risk concept</td>
<td>- Evaluation of the risks caused by technology within the societal context</td>
<td>- Knowledge about the mode science and society handle current environmental risks (examples gene- and nanotechnology)</td>
<td>- Knowledge about handling risks (e.g. precautionary principle, protection goal, damage definition, ethics)</td>
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<tr>
<td>Content</td>
<td>Knowledge about possibilities for sustainable innovation</td>
<td>- Risks and technical systems (risk categories, risk perception, risk management)</td>
<td>- Illustration with case studies (nanotechnology)</td>
<td>- Implementation (politics, science, media, etc.)</td>
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<tr>
<td>Lecture notes</td>
<td>Copies of slides and selected documents will be distributed</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The lecture is held biweekly (for 2 hours). The dates are 3.9.; 30.9. (instead of 7.10); 21.10; 4.11.; 18.11.; 2.12.; 16.12.</td>
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<th>Course Code</th>
<th>Course Title</th>
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<th>Generator</th>
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<tr>
<td>860-0023-00L</td>
<td>International Environmental Politics</td>
<td>3</td>
<td>W</td>
<td>2V</td>
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<tr>
<td>T. Bernauer</td>
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<tr>
<td>Abstract</td>
<td>This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.</td>
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<tr>
<td>Objective</td>
<td>The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.</td>
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</table>
This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Lecture notes

- Assigned reading materials and slides will be available via Moodle.

Literature

- Assigned reading materials and slides will be available via Moodle.

Prerequisites / notice

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

851-0735-10L Business Law

| Number of participants limited to 100 |
| W | 2 credits | 2V | P. Peyrot |

Abstract

Particularly suitable for students of D-ITET, D-MAVT

Objective

The students shall obtain a basic knowledge about business law. They shall be able to recognize and evaluate issues in the area of business law and suggest possible solutions.

The students shall obtain the following competence:
- They shall obtain a working knowledge on the legal aspects involved in setting up and managing an enterprise.
- They shall be acquainted with corporate functions as contracting, negotiation, claims management and dispute resolution.
- They shall be familiar with the issues of corporate compliance, i.e. the systems to ascertain that all legal and ethical rules are observed.
- They shall be able to contribute to the legal management of the company and to discuss legal issues.
- They shall have an understanding of the law as a part of the corporate strategy and as a valuable resource of the company.

Lecture notes

A comprehensive script will be made available online on the moodle platform.

101-0515-00L Project Management

| W | 2 credits | 2G | C. G. C. Marxt |

Abstract

The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established concepts and methods for project organization, planning, execution and evaluation are introduced and major challenges discussed. The course includes an introduction on specialized project management software as well as agile project management concepts.

Objective

Projects are not only the base of work in modern enterprises but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company wide success.

Content

- Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

Lecture notes

No lectures. The lecture slides and other additional material will be available for download from Moodle a week before each class.

151-0757-00L Environmental Management

| W | 2 credits | 2G | R. Züst |

Abstract

An environmental management system has the objective to continuously improve the environmental performance of the activities, products and services of a company. The company has to introduce different management procedures. The goal of this lecture is to provide basics and specific procedure to implement the environmental dimension in the planning and decision making processes of an organisation.

Objective

Overview on environmental management and environmental management systems, general methods and principles.

Content

- Introduction to environmental management / environmental management systems, energy and material flows; economical and ecological problems in industry; characterisation of an enterprise (incl. management handbook); structure and contents of an environmental management system; overview on the ISO 14001 ff. series; methods for environmental evaluation and assessment; integrated management systems; planning methodology and life-cycle-design concept; planning example
Lecture notes
Information about environmental management and environmental management systems will be provided by a CD or mail.

Literature
a list with literatures and links will be provided

Prerequisites / notice
Delivery of a case study, worked out in groups. Language: Teaching in English on request.

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<th>Course Code</th>
<th>Course Title</th>
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<th>2 credits</th>
<th>2G</th>
<th>Taught by</th>
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<tbody>
<tr>
<td>851-0180-00L</td>
<td>Research Ethics</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>G. Achermann, P. Emch</td>
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</table>

Abstract
Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Objective
Participants of the course Research Ethics will
- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles); and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;

Content
I. Introduction to Moral Reasoning
1. Ethics - the basics
1.1 What ethics is not… 1.2 Recognising an ethical issue (awareness) 1.3 What is ethics? Personal, cultural and ethical values, principles and norms 1.4 Ethics: a classification 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
2.1 What is normative ethics? 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories 2.3 The plurality of normative theories (moral pluralism) 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
3.1 How (not) to approach ethical issues 3.2 What is a moral dilemma? Is there a correct method for answering moral questions? 3.3 Methods of making ethical decisions 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities
1. Integrity in research and research misconduct
1.1 What is research integrity and why is it important? 1.2 What is research misconduct? 1.3 Questionable/Detrimental Research Practice (QRP/DRP) 1.4 What is the incidence of misconduct? 1.5 What are the factors that lead to misconduct? 1.6 Responding to research wrongdoing 1.7 The process of dealing with misconduct 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
2.1 Data collection and recordkeeping 2.2 Analysis and selection of data 2.3 The (mis)representation of data 2.4 Ownership of data 2.5 Retention of data 2.6 Sharing of data (open research data) 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
3.1 Background 3.2 Criteria for being an author 3.3 Ordering of authors 3.4 Publication practices

III. Research Ethics – External responsibilities
1. Research involving human subjects
1.1 History of research with human subjects 1.2 Basic ethical principles – The Belmont Report 1.3 Requirements to make clinical research ethical 1.4 Social value and scientific validity 1.5 Selection of study participants – the concept of vulnerability 1.6 Favourable risk-benefit ratio 1.7 Independent review - Ethics Committees 1.8 Informed consent 1.9 Respect for potential and enrolled participants

2. Social responsibility
2.1 What is social responsibility? a) Social responsibility of the individual scientist b) Social responsibility of the scientific community as a whole; 2.2 Participation in public discussions; a) Debate & Dialogue b) Communicating risks & uncertainties c) Science and the media 2.3 Public advocacy (policy making)

3. Dual use research
3.1 Introduction to Dual use research 3.2 Case study – Censuring science? 3.3 Transmission studies for avian flu (H5N1) 3.4 Synthetic biology

Lecture notes
Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.

Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) observed success factors for many years!:
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g., taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more…).

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Competencies and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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<td>Domain C - Social Competencies</td>
<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>Taught by</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0453-00L</td>
<td>Strategic Supply Chain Management</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Wagner</td>
</tr>
</tbody>
</table>

**Abstract**
The course offers an introduction to the theory and practice of supply chain management. Students will learn to develop supply chain strategies and supply chain networks based on firms' competitive strategies and marketing priorities.

**Objective**
After completing this course:
1. Students can explain the importance of supply chain management for a firm's strategy and success.
2. Students are able to apply the tools and methods used to optimize a supply chain structure.
3. Students can differentiate supply chain network designs in specific company and sector settings.
4. Students can describe and evaluate fundamental logistics and supply chain concepts.
5. Students are able to explain elements of a supply chain structure and their importance for supply chain strategy.
6. Students are familiar with current developments and trends in supply chain practices.

**Content**
Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage in globalized (supply) markets with numerous partners and competitors. While taking into account future opportunities and risks, effective supply chains ought to be aligned with and support the achievement of the firm's corporate, business, and product strategies. This course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains.

**Literature**

**Prerequisites / notice**
Case study assignments make up 30% of the final grade. Details on submission and grading are provided within the course and on "Performance Assessment". The maximum grade can only be achieved if both the exam is taken and all case studies are submitted.

Students should install MS Excel and the Excel Solver before class, as it is used for within-class exercises. Students without the program and add-in installed may nevertheless participate within groups during the exercises.

**Lecture notes**
The course material will be made available for download on Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=15222

All organizational matters will be handled by the teaching assistant Sarah Schaumann (schaumannn@ethz.ch). Please use the SSCM Class Forum on Moodle as a first point of contact.

**Prerequisites / notice**
None

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**535-0667-00L**
**Communication and Social Competences**

<table>
<thead>
<tr>
<th>W</th>
<th>1 credit</th>
<th>1V</th>
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</thead>
<tbody>
<tr>
<td>Communication and Social Competences</td>
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</tbody>
</table>

**Objective**
Introduction in basic skills for increasing the effectiveness and efficiency of students' daily work.

**Content**
- Corresponding learning goals

**Lecture notes**
Handouts and working papers.

**Literature**
- Braun Walter, Die (Psycho-) Logik des Entscheidens, Fallstricke, Strategien und Techniken im Umgang mit schwierigen Situationen, Huber, 2010
- Stadelwieser Jürg, Kommunikation als Schlüssel zum Erfolg, Tobler, 2000 (vergriffen/Bibliothek).

**Prerequisites / notice**
None

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**701-0703-00L**
**Environmental Ethics**

<table>
<thead>
<tr>
<th>W</th>
<th>2 credits</th>
<th>2V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Ethics</td>
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</tbody>
</table>

**Objective**
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This course introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

**Content**
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarisation with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

**Lecture notes**
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

**Literature**
- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neill et al., Environmental Values, 2008
- Konrad Ott/Jan Dierks/Lieske Vogel-Kleschin, Handbuch Umweltethik, 2016

General introductions:
- Marcus Düwell et al. (Hrsg.), Handbuch Ethik, 2. Auflage, Stuttgart (Metzler Verlag), 2008
- Johann S. Ach et. al. (Hrsg.), Grundkurs Ethik 1. Grundlagen, Paderborn (mentis) 2008
The procedure for accumulating CP will be explained at the start of term. We expect participants to engage in and contribute to discussions for keeping the course interesting and lively.

376-1581-00L Cancer: Fundamentals, Origin and Therapy

Abstract

Objective
Students are able to describe selected chemicals, biological and molecular processes that occur in cells spontaneously or after physical or chemical exposure and resulting in a tumor. They are able to list important cancer-inducing agents and explain the respective mechanism of action. They have knowledge of significant risk factors for cancer diseases. They are confronted with the basics of toxicology and they can explain the principle of the most common therapeutic strategies.

Content
The lecture deals with problems of tumor epidemiology (causes, mortality, incidence). Cancer is delineated as a multi-step process. Classes of chemical compounds that induce cancer are discussed as well as the reactive metabolites that may be built from. Covalent binding to DNA is discussed and different types of mutations resulting thereof. A selection of proto-oncogenes and tumor suppressor genes is presented. Their function will be discussed as well as the changes which are found in these genes in tumor cells, starting from single nucleotide exchanges up to large deletions.

The reason for genetic predisposition to cancer will be discussed as well as cancer relevant aspects of cell cycle regulation. The role of tumor microenvironments and phenomenons like angiogenesis and metastasis are presented as well as the mechanisms that protect the genome from mutagenic damage. Further subjects address old and new strategies of cancer treatment. Personalised cancer treatment.

Lecture notes
Handouts with reproductions of all presented transparencies will be distributed.

Literature

Prerequisites / notice
The lecture requires an active participation of the students. All students will participate in individual or group work focussing on specific subject of the lecture. Students will have ample time for preparation during lecture time.

Bachelor’s Thesis

Number Title Type ECTS Hours Lecturers
752-0220-20L Bachelor’s Thesis O 15 credits 32D Lecturers

Abstract
The Bachelor Thesis completes the Bachelor programme and consists of a scientific project carried out independently under the tutorship of a lecturer at D-HEST.

Objective
The Bachelor Thesis aims at fostering the student's ability to independent, structured and scientific working and at deepening their knowledge in a specific field.

Food Science Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
<td></td>
<td>Lecturers</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td></td>
</tr>
</tbody>
</table>

Key for Hours

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

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Management, Technology and Economics (General Courses)

### General Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>351-0778-00L</td>
<td>Discovering Management</td>
<td>Z</td>
<td>3</td>
<td>3G</td>
<td>B. Clarysse, Brusoni, E. Fleisch, G. Grote, V. Hoffmann, T. Netland,</td>
</tr>
<tr>
<td></td>
<td>Entry level course in management for BSc, MSc and PHD students at all levels not belonging to D-MTEC. This course can be complemented with Discovering Management (Exercises) 351-0778-01.</td>
<td></td>
<td></td>
<td></td>
<td>Y. R. Shrestha, P. Tinguely, L. P. T. Vandeweghe</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
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<td></td>
<td>The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>In particular, the aims of the course are to:</td>
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<td>(1) broaden understanding of management principles and frameworks</td>
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<td>(2) advance insights into the sources of corporate and entrepreneurial success</td>
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<td>(3) develop skills to apply this knowledge to real-life managerial problems</td>
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<td>License</td>
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<td></td>
<td>The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
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<td></td>
<td>The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.</td>
</tr>
<tr>
<td></td>
<td>Taught competencies</td>
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<td></td>
<td>The theory sessions will follow a &quot;lecture-style&quot; approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.</td>
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<td>Through small group work, you will develop analyses of each of the cases. Each group will also submit a &quot;pitch&quot; with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.</td>
</tr>
<tr>
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<td></td>
<td>All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td>License</td>
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<td></td>
<td></td>
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<td>Taught competencies</td>
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<td></td>
<td></td>
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<td></td>
<td>All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.</td>
</tr>
<tr>
<td>351-0778-01L</td>
<td>Discovering Management (Exercises)</td>
<td>Z</td>
<td>1</td>
<td>1U</td>
<td>B. Clarysse, L. P. T. Vandeweghe</td>
</tr>
<tr>
<td></td>
<td>Complementary exercises for the module Discovering Management.</td>
<td></td>
<td></td>
<td></td>
<td>Prerequisite: Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>This course is offered complementary to the basis course 351-0778-00L, &quot;Discovering Management&quot;. The course offers an additional exercise.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>The general objective of Discovering Management (Exercises) is to complement the course &quot;Discovering Management&quot; with one larger additional exercise.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
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<td></td>
<td>Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.</td>
</tr>
<tr>
<td></td>
<td>License</td>
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<td></td>
<td>Students who are enrolled for “Discovering Management Exercises” are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management.</td>
</tr>
<tr>
<td></td>
<td>Taught competencies</td>
<td></td>
<td></td>
<td></td>
<td>Students have the option to either write this alone or in a group of two students.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. Students following this course should also be enrolled for course 351-0778-00L, &quot;Discovering Management&quot;.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>These course materials will form the point of departure for the lectures, class discussions and team work.</td>
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<td>The theory sessions will follow a &quot;lecture-style&quot; approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.</td>
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<td></td>
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<td>Through small group work, you will develop analyses of each of the cases. Each group will also submit a &quot;pitch&quot; with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.</td>
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<td></td>
<td>All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.</td>
</tr>
<tr>
<td>351-0555-00L</td>
<td>Open- and User Innovation</td>
<td>Z</td>
<td>3</td>
<td>2G</td>
<td>S. Häfliger, S. Spaeth</td>
</tr>
<tr>
<td></td>
<td>The course introduces the students to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies.</td>
<td></td>
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</tbody>
</table>
Objective

The course includes both lectures and exercises alternately. The goal is to understand the opportunity of user innovation for management and develop strategies to harness the value of user-developed ideas and contributions for firms and other organizations.

The students actively participate in discussions during the lectures and contribute presentations of case studies during the exercises. The combination should allow to compare theory with practical cases from various industries.

The course presents and builds upon recent research and challenges the students to devise innovation strategies that take into account the availability of user expertise, free and public knowledge, and the interaction with communities that span beyond one organization.

Performance assessment will be: a written group essay based on the open/user innovation case that participants will research and present during the block seminar (including the slides). Each group will have to hand in a 15-20 page essay, details on the required format and the content will be distributed during the course. Active class participation is required.

Content

This course on user innovation extends courses on knowledge management and innovation as well as marketing. The students are introduced to the long-standing tradition of actively involving users of technology and other knowledge-intensive products in the development and production process, and through own cases they develop an entrepreneurial understanding of product development under distributed, user-centered, or open innovation strategies. Theoretical underpinnings taught in the course include models of innovation, the structuration of technology, and an introduction to entrepreneurship.

Lecture notes

The slides of the lectures are made available and updated continuously through the SMI website:

Literature

Relevant literature for the exam includes the slides and the reading assignments. The corresponding papers are either available from the author online or distributed during class.

Reading assignments: please consult the SMI website:

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Type</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0511-00L</td>
<td>Managerial Economics</td>
<td>Z</td>
<td>4 credits</td>
<td>M. Lohmann, P. Egger, M. Köthenbürger</td>
</tr>
</tbody>
</table>

Abstract

“Managerial Economics” provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective

The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature


Prerequisites / notice

The course targets both Bachelor and Master students. No prior knowledge in the areas of Economics and Management is required.

Management, Technology and Economics (General Courses) - Key for Type

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

Key for Hours

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

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Core courses

General Management and Human Resource Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0341-00L</td>
<td>Introduction to Management</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>Z. Zagorac-Uremovic, J. O'Neil</td>
</tr>
</tbody>
</table>

Abstract
This course is an introduction to the critical management skills involved in planning, organizing, leading and controlling an organization. By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate routine operations in order to meet evolving customers’ and societal needs. The students will achieve these goals by being able to:
- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships.

Content
This course follows a ‘systemic’ view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will furthermore discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between those elements and on the application of a selection of tools and methods.

Literature
Selected readings from the book and additional learning materials will be available on the course Moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15262

Prerequisites / notice
Throughout the course different session preparation assignments, like book chapters or case studies will be handed out to the students on Moodle. This preparation is required to participate in the lectures. The final exam of the present course is online exam. The final exam is requested for all types of students (BSc, MSc, MA, PhD, and Exchange students). It is not possible to retake the exam within the same term or academic year.

Strategy, Markets and Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0387-00L</td>
<td>Corporate Sustainability</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>V. Hoffmann, C. Bening-Bach, N. U. Blum, J. Meuer</td>
</tr>
</tbody>
</table>

Abstract
The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the 2nd half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food.

Objective
Students
- assess the limits and the potential of corporate sustainability for sustainable development
- develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method.
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams with different output formats (tv-style debate, consultancy pitch, technology model walk-through, campaign video)

Content
In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share his insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.

Lecture notes
http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

Literature
Presentation slides will be made available on moodle prior to lectures.

Prerequisites / notice
TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.
Students who take this course will increase their knowledge of marketing, its effect on consumer behavior and its role in creating long-term value. The course will introduce important concepts, frameworks and methods for marketing decision-making. A focus will be on managing customer relationships with the help of targeted promotions and data collected through digital technologies.

After taking the class, students will be able to:

1) Define what marketing is and describe its role at different stages of the value chain
2) Apply psychological theories to analyze behavior (e.g., purchase behavior) and identify the needs of (prospective) customers in consumer and business markets
3) Design elements of the marketing mix—e.g., develop new products and set prices—in a way that creates long-term value
4) Create an efficient and effective marketing mix that attracts and engages customers, e.g., by running targeted promotions
5) Use quantitative methods and customer data to manage relationships with customers

The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

The course is designed to be “hands-on”, with opportunities to apply skills on business cases involving real-world marketing data. It will feature guest lectures from industry experts.

The class might be taught in an in-person, remote or in a hybrid format.

The course might comprise mandatory and supplemental reading material. Other literature may be assigned in class.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

### Strategic Management

**363-0392-00L**  
**W+ 3 credits 2G Y. R. Shrestha**

**Number of participants limited to 80.**

This course conveys concepts and methods in strategic management, with a focus on competitive strategy. Competitive strategy aims at improving and establishing position of firms within an industry.

The lecture “Strategic Management” is designed to teach relevant competences in strategic planning and -implementation, for both professional work-life and further scientific development. The course provides an overview of the basics of strategy and the most prevalent concepts and methods in strategic management. The course is given as a combination of lectures about concepts/methods, and case studies where the students solve strategic issues of the case companies. In two sessions, the students will also be addressing real-time strategic issues of firms that are represented by executives.

**Content**

<table>
<thead>
<tr>
<th>Date</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.09.2021</td>
<td>Guest Lecture (Dr. Berg) and Introduction</td>
</tr>
<tr>
<td>04.10.2021</td>
<td>Strategy concepts</td>
</tr>
<tr>
<td>18.10.2021</td>
<td>Industry dynamics I: Industry analysis + Case Studies</td>
</tr>
<tr>
<td>25.10.2021</td>
<td>Guest Lecture (Patrick Warnking, Google) + Case Studies</td>
</tr>
<tr>
<td>01.11.2021</td>
<td>Industry dynamics II: Analysis of technology and innovation + Cases</td>
</tr>
<tr>
<td>15.11.2021</td>
<td>The resource-based theory of the firm + Cases</td>
</tr>
<tr>
<td>22.11.2021</td>
<td>The knowledge-based theory of the firm + Cases</td>
</tr>
<tr>
<td>29.11.2021</td>
<td>Guest Lecture (Andy Staubli, PwC) and course summary</td>
</tr>
</tbody>
</table>

Strategic Management offers a combination of lectures about concepts/methods, and case studies where the students solve strategic issues of the involved companies. This aims at offering students a profound theoretical understanding of important and current topics and also offer an opportunity to present these concepts in front of an audience.

This course conveys concepts and methods in strategic management, with a focus on competitive strategy. Competitive strategy aims at analyzing and establishing position of firms within an industry, securing firm performance. Thus, the course focuses on a number of important topics, such as the evolution of industry, industry structure, the analysis of a firm’s resources- and knowledge, and innovation. In addition, student groups will hold presentations on the four main topics of this class, to further develop concepts and enhance understanding. The presentations will cover Industry Dynamics I, Industry Dynamics II, Resource Based View of the Firm, Knowledge Based View of the Firm. For all presentations, selected Harvard Business Cases will be used as a common ground for students to start from.

Students are also expected to read and understand the required readings (approx. 15 items) that cover the most important papers and articles from the past 30 years in management and strategy research.

To underline the relevance of Strategic Management in firms, decision makers from companies in Switzerland will be holding guest lectures and give their talk on strategy in practice and give insight on current topics in the field.
This course looks at technology and innovation management as a process. Continuously, organizations are faced with a fundamental challenge of innovation, at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change.

Objective
- understand the core concepts necessary to analyze how innovation happens
- master the most common methods and tools organizations deploy to innovate
- develop the ability to critically evaluate the innovation process, and act upon the main obstacles to innovation

Content
This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at how do firms organize to take these decisions? What kind of management skills are necessary to take them? What kind of tools and methods are deployed to sustain managerial decision-making in highly volatile environments? These are the central questions on which this course focuses, relying on a combination of lectures, case-based discussion, guest speakers, simulations and group work.

Prerequisites / notice
The course content and methods are designed for students with some background in management and/or economics.
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

POM is concerned with the business processes that transform input into output and deliver products and services to customers. POM is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota. To mention a few (although sufficient and important in a big part to POM), finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance management. (3) Operations improvement, including problem-solving and the use of new technologies in POM ("Industry 4.0" / digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms' competitive strategies and marketing priorities.

After completing this course:
1. Students can explain the importance of supply chain management for a firm's strategy and success
2. Students are able to apply the tools and methods used to optimize a supply chain structure
3. Students can differentiate supply chain network designs and their applicability in specific company and sector settings
4. Students can describe and evaluate fundamental logistics and supply chain concepts
5. Students are able to explain elements of a supply chain structure and their importance for supply chain strategy
6. Students are familiar with current developments and trends in supply chain practice

Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage in globalized (supply) markets with numerous partners and competitors. While taking into account future opportunities and risks, effective supply chains ought to be aligned with and support the achievement of the firm's corporate, business and product strategies. This course will familiarize students with modern supply chain management theory and practice to develop and manage supply chains.

Starting with the corporate strategy, firms align their supply chain strategy. They have to manage trade-offs, such as efficiency and responsiveness. Understanding a supply chain's role within a firm and the implications of supply chain strategies for firm performance are the foundations of the course.

Building on the foundations, students get familiarized with the development of a supportive supply chain structure. This structure is in its core made up by a few essential elements, such as facilities, inventory management, demand management, and supply chain management in general. The strong relationship between supply and demand drives to define a supply chain structure. Students will learn important elements in supply chain structure, including for example forecasting methods and network design modeling and optimization. Case study assignments and practical exercises within lectures allow students to gain hands-on experience and enhance their knowledge.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course furthermore encourages student involvement within lectures, in exchange with peers and with guest speakers. Case study assignments and tools for self-assessment help students to learn actively and continuously throughout the course.

Lecture notes
The course material will be made available for download on Moodle:

https://moodle-app2.let.ethz.ch/course/view.php?id=15222

All organizational matters will be handled by the teaching assistant Sarah Schaumann (sschaumann@ethz.ch). Please use the SSCM Class Forum on Moodle as a first point of contact.

The following textbook is recommended:

The following textbook is supplementary:

Case study assignments make up 30% of the final grade. Details on submission and grading are provided within the course and on “Performance Assessment”. The maximum grade can only be achieved if both the exam is taken and all case studies are submitted.

Students should install MS Excel and the Excel Solver before class, as it is used for within-class exercises. Students without the program and add-in installed may nevertheless participate within groups during the exercises.

Quantitative and Qualitative Methods for Solving Complex Problems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0305-00L</td>
<td>Empirical Methods in Management</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
</tr>
</tbody>
</table>

In this class, students learn how to understand and conduct empirical research. It will enable them to manage a business based on evidence-based decision-making. The class includes group assignments, where students will cover small parts of the lecture content in self-created videos.

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

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

The lecture will be taught online this fall semester. Therefore, it involves group work, where students form groups in order to create small learning videos, which cover small parts of the lecture. These videos will be shown and discussed in the online lecture and will make up 30% of the final grade. Part of this assignment will be the evaluation of videos from other students. The preparation of the videos will also prepare students for the final exam. In addition to that, there will be some non-mandatory online exercises as an additional opportunity to prepare for the exam.
The course includes out-of-class assignments and projects to give students some hands-on experience in conducting empirical research in management. Projects will focus on one particular aspect of empirical research, like the formulation of a research question or the design of a study. Students will form groups and create a learning video regarding one specific topic. Assignments will be graded and need to be turned in on time as they will be shown and discussed in class. Students will also have to evaluate the videos of other student groups. Online class participation is encouraged and can greatly improve students’ learning. In this spirit, students are expected to attend class regularly and come to class prepared.

### Literature

Literature and readings will be announced. For a basic understanding we recommend the Handbook of Good Research by Jürgen Brock and Florian von Wangenheim.

### Prerequisites / notice

This course is structured along three main tasks:

1. **Finding solutions**
   - Introducing the problem-solving cycle
   - Understanding the integration of quantitative models into the managerial decision process

2. **Implementing solutions**
   - Project management
   - Critical path method
   - Quality control feedback loop

3. **Controlling solutions**
   - Vensim software
   - Feedback cycles
   - Control parameters
   - Instabilities
   - Chaos
   - Oscillations and cycles
   - Supply and demand

The course is structured along three main tasks: *Analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics.*

### Abstract

- **Operations Research**
  - Introduction to building and using quantitative models in a business/industrial environment
  - Introduction to basic optimization techniques (Linear Programming and extensions, network flows, integer programming, dynamic and stochastic optimization)
- **Systems Dynamics and Complexity**
  - The economic environment of today's companies is characterized by high cost pressure, declining margins, intensified international competition, rising customer requirements and increasingly strict regulations. Strategic and operational decisions at all management levels are becoming more and more complex due to the increasing amount of data, interrelationships, conditions and target criteria to be considered. Often it is no longer possible to solve operational tasks with experience and common sense alone and to adequately estimate the consequences of decisions without software support.

Quantitative models and methods of operations research and operations management offer decision support for complex problems. Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be analysed and optimized using suitable solution methods. A large number of quantitative real-world problems can be formulated and solved in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network design, airline fleet assignment and revenue management.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The following topics are covered in detail:

- Introduction to system modeling and operations research
- Linear models and the importance of linear programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

### Prerequisites / notice

Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.

### Literature

Any standard textbook in Operations Research is a useful complement to the course.

### Lecture notes

A printed script will be made available.

### Number

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0541-00L</td>
<td>Systems Dynamics and Complexity</td>
<td>Lecture notes</td>
<td>3 credits</td>
<td>3G</td>
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<tr>
<td>363-1004-00L</td>
<td>Operations Research</td>
<td>W*</td>
<td>3 credits</td>
<td>2G</td>
</tr>
</tbody>
</table>

### Micro and Macroeconomics

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.
The learning objectives of the course are:

- Students must be able to discuss basic principles, problems and approaches in microeconomics.
- Students can analyse and explain simple economic principles in a market using supply and demand graphs.
- Students can contrast different market structures and describe firm and consumer behaviour.
- Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
- Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
- Students can apply simple mathematical concepts on economic problems.

The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. Economic considerations and discussions are not part of classical engineering and science study programmes. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course will help the students to look at the contents of their own studies from a different perspective and to illustrate how these affect the economy as a whole. Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade


This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare economics concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability economics, and international resource and environmental problems. By attending this course, students will be able to:

Objective

- determine the cost of production.
- understand the principles of cost accounting.
- prepare the different financial reports.
- establish a balance sheet and an income statement.
- record business transactions on the different types of accounts.

Content

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare economics concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability economics, and international resource and environmental problems. Second, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Third, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Literature

N. Gregory Mankiw and Mark P. Taylor (2020), "Economics", 5th edition, South-Western Cengage Learning. The book can also be used for the course 'Principles of Macroeconomics' (Sturm)

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:


Complementary:


GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Author: Mikroökonomie.

GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

363-0537-00L Resource and Environmental Economics

Abstract

Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

Objective

A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Content

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare economics concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature


Financial Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0711-00L Accounting for Managers</td>
<td>W+</td>
<td>3</td>
<td>2V</td>
<td>J.-P. Chardonnens</td>
<td></td>
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</table>

Autumn Semester 2021
Content

The first part of the course is devoted to financial accounting. It teaches the principles of double-entre accounting and deals with the recording of commercial transactions on accounts. It describes the work to be carried out at the closing in order to prepare the financial reports according to the generally accepted accounting principles. This type of accounting information is primarily intended for investors and shareholders.

The second part of the course describes the principles of management accounting and explains the different costing methods. It aims to determine the manufacturing cost of production of the different products and services using full and variable costing methods. The accounting information focuses on the internal needs of managers for the purpose of budget preparation and profitability analysis.

Prerequisites / notice

This course is a prerequisite for the course Financial Management.

363-0561-00L

<table>
<thead>
<tr>
<th>Financial Market Risks</th>
<th>W+</th>
<th>3 credits</th>
<th>2G</th>
<th>D. Sornette</th>
</tr>
</thead>
</table>

Abstract

I aim to introduce students to the concepts and tools of modern finance and to make them understand the limits of these tools, and the many problems met by the theory in practice. I will put this course in the context of the on-going financial crises in the US, Europe, Japan and China, which provide fantastic opportunities to make the students question the status quo and develop novel solutions.

Objective

The course explains the key concepts and mechanisms of financial economics, their depth and then stresses how and why the theories and models fail and how this is impacting investment strategies and even a global view of citizenship, given the present developing crises in the US since 2007 and in Europe since 2010.

- Development of the concepts and tools to understand these risks and master them.
- Working knowledge of the main concepts and tools in finance (Portfolio theory, asset pricing, options, real options, bonds, interest rates, inflation, exchange rates)
- Strong emphasis on challenging assumptions and developing a systemic understanding of financial markets and their many dimensional risks

Content

1- The Financial Crises: what is really happening? Historical perspective and what can be expected in the next decade(s). Bubbles and crashes. The illusion of the perpetual money machine.

2- Risks in financial markets
- What is risk?
- Measuring risks of financial assets
- Introduction to three different concepts of probability
- History of financial markets, diversification, market risks

3- Introduction to financial risks and its management.
- Relationship between risk and return
- Portfolio theory: the concept of diversification and optimal allocation
- How to price assets: the Capital Asset Pricing Model
- How to price assets: the Arbitrage Pricing Theory, the factor models and beyond

4- Financial markets: role and efficiency
- What is an efficient market?
- Financial markets as valuation engines: exogeneity versus endogeneity (reflexivity)
- Deviations from efficiency, puzzles and anomalies in the financial markets
- Financial bubbles, crashes, systemic instabilities

5- An introduction to Options and derivatives
- Calls, Puts and Shares and other derivatives
- Financial alchemy with options (options are building blocs of any possible cash flow)
- Determination of option value; concept of risk hedging

6- Valuation and using options
- A first simple option valuation model
- The Binomial method for valuing options
- The Black-scholes model and formula
- Practical examples and implementation
- Realized prices deviate from these theories; volatility smile and real option trading
- How to imperfectly hedge with real markets?

7- Real options
- The value of follow-on investment opportunities
- The timing option
- The abandonment option
- Flexible production
- Conceptual aspects and extensions

8- Government bonds and their valuation
- Relationship between bonds and interest rates
- Real and nominal rates of interest
- Term structure and Yields to maturity
- Explaining the term structure
- Different models of the term structure

9- Managing international risks
- The foreign exchange market
- Relations between exchanges rates and interest rates, inflation, and other economic variables
- Hedging currency risks
- Currency speculation
- Exchange risk and international investment decisions

Lecture notes

Lecture slides will be available on the site of the lecture

Literature

Corporate Finance
Brealey / Myers / Allen
Eight edition

+ additional paper reading provided during the lectures
Objective
Learning outcomes professional competence
- The students learn and understand the management basics of inter-firm cooperation and organizational networks (business models, incl. risk, communication, etc.)
- realize the value creation potentials of alliances (added value)
- understand underlying theoretical models (Transaction cost theory, principal agent, game theory)
- Identify and understand specific forms of collaboration (Strat. All., JV, Networks, M&A, etc.)
- Apply tools hands on in real companies (in coll. with companies)

Learning outcomes methodological competence
- Writing academic papers
- Developing structured documentation of interviews
- Transferring theory directly into application
- Contributing to the learning journey

Learning outcomes social competence
- Work together with industrial partners
- Improving communication skills as basics for collaboration
- Developing and applying team work skills
- Coping with conflicts resolution in teams

Content
The constantly augmenting complexity of technologies and systems, the increased pressure caused by competition, the need for shortening time-to-market and the thereby implied growing risks force organizations to increasingly focus on core competencies. Collaboration with external partners is a key value creation opportunity for successful ventures. This type of cooperation also has implications on daily management activities. This lecture will provide a better understanding of special requirements needed for management of cooperation issues.

Content:
- Introduction to theory and management of inter-firm collaboration and networks.
- Description of the formation, management and evolution of collaborations and networks.
- Collaborations in marketing, development, manufacturing (e.g. NUMMI).
- Special forms of collaborations: mergers & acquisition (e.g. pre- and post-merger activities, joint venture, strategic alliances (e.g. Doz & Hamel, networks, virtual communities)

Learning journey:
In an introductory lecture we will give an overview of the theoretical framework and explain the concept of the lecture (first week of semester, Sept. 19, 2019). In weeks 2-5 you will work on a first assignment on six different aspects of the underlying framework: strategy and activities, structure and process, culture and people orientation, interaction and roles, risk and trust, knowledge and learning. This first assignment will give you the basics to participate in the second part (Nov. 7-8, 2019) of this seminar. There you will present the results of the first assignment and get additional theoretical input to perform the 2nd assignment. The second assignment will be to analyze real alliance projects in the partner companies. The final lesson will be used as a best practice exchange (Dec. 19, 2019).

Lecture notes
- Lecture script
- Current course material
- Harvard Case Studies
- Reader with current papers

Literature
A list with recommended publications will be distributed in the lecture.

Classic Books:
HBR Collaborating Effectively ISBN 978-1-4221-6264 4
HBR on Mergers and Acquisitions: ISBN 1-57851-555-6

Prerequisites / notice
The number of students participating in the lecture is limited to 30.
Content
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology intensive markets by using real life cases. Students will have to work in groups and together solve past, current and future managerial problems in the form of cases. The team member composition will rotate for each case, enabling students to foster their teamwork abilities besides the application of theoretical concepts to the applied case questions. The students will have to present their case solutions to the lecturer and a top executive of a leading Swiss company (details see below). Also, they will be enabled to compare their solutions with what has actually been done or is yet to be done.

The three case studies presented in this course cover real managerial issues of the Swiss manufacturer Bühler AG (www.buhlergroup.com). A Bühler top executive will present the cases and discuss the students' presentations and solutions. As such, the course allows for in-depth discussions of the real-life case solution with the C-level manager and hereby enables students to transfer their learnings from theoretical considerations to the applied field. The course will be rounded off with a day-visit to the Bühler facilities in Uzwil, Switzerland, where students will have the chance to further connect with management and discuss the acquired key concepts, tools, and case study insights on site.

Prerequisites / notice
In addition to course enrolment, students have to apply for this course by sending a CV and a short motivation letter until 20.08.2021 to Theresa Schachner: tschachner@ethz.ch.

363-0393-00L Corporate Strategy
Due to didactic considerations, the number of participants for this course is limited to 45.

Objective
This course focuses on the challenges in managing multi-business corporations, and covers topics related to the vertical and horizontal scope of business activities.

Content
The course is a combination of lectures about concepts/methods, guest lectures, case studies, and individual assignments.

Large- and medium-sized corporations play a central role in the economic activity of most developed and developing countries. Many of these organizations perform multiple business activities in multiple markets. In the face of increasing international competition, globalization, technological development, deregulation, and the emergence of new markets and industries, operating such a portfolio of business activities poses important managerial challenges forcing corporations to continuously re-consider their vertical and horizontal scope and boundaries.

The course Corporate Strategy draws from a wide range of theories and methods to develop an understanding of the conceptual frameworks, debates, and developments concerning decisions associated with the management of multi-business corporations. We will cover the key questions driving a firm's corporate strategy, including:

- What do institutional forces impact corporate strategy?
- In what markets to compete with which businesses?
- Which activities should be performed by the firm and which should be outsourced (i.e. "make" or "buy" decisions)?
- What are the most appropriate approaches to growth and divestiture?
- How do institutional forces impact corporate strategy?

Specifically, we will examine how organizations manage their portfolio of business activities and markets to achieve competitive advantage through vertical integration, cooperative strategies such as strategic alliances and joint ventures, corporate diversification, mergers and acquisitions, divestitures, and globalization/international strategies, and strategic renewal.

Prerequisites / notice
Having participated in the course Strategic Management by Prof. Georg von Krogh/Dr. Stephan Herting is an advantage but not a requirement.

Taught competencies
- Domain A - Subject-specific Competencies: Concepts and Theories, Analytical Competencies, Problem-solving, Critical Thinking, Self-direction and Self-management

The course homepage can be found at: http://www.smi.ethz.ch/education/corporate-strategy.html

363-1065-00L Design Thinking: Human-Centred Solutions to Real World Challenges
Does not take place this semester.

Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Information and application: http://sparklabs.ch/

Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:

- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0393-00L</td>
<td>Corporate Strategy</td>
<td>3 credits</td>
<td>2V</td>
</tr>
<tr>
<td>363-1065-00L</td>
<td>Design Thinking: Human-Centred Solutions to Real World Challenges</td>
<td>5 credits</td>
<td>5G</td>
</tr>
</tbody>
</table>

The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session.

Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

363-1028-00L
Entrepreneurial Leadership
Limited number of participants.

Students apply for this course via the official website no later than August 23. (https://www.mtec.ethz.ch/studies/special-programmes/els.html).

Once your application is confirmed, registration in myStudies is possible.

Abstract
This seminar provides master and PhD students at MTEC with the challenging opportunity of a real case on strategy, innovation and leadership in close collaboration with the top management of a leading Swiss manufacturing company: Georg Fischer.

Objective
The general objective of the course is to enable MTEC students to develop leadership skills by dealing with real-world business problems, thinking critically about the concepts discussed in their study programs and learning how to apply these concepts to provide practical implications. It provides students with coaching and mentoring from senior leaders in the company and professors from D-MTEC to bridge the gap between theory and practice.

Content
This seminar provides ambitious ETH students and doctoral candidates with a rewarding learning opportunity: a real case study of strategy and innovation in close collaboration with the top management of an outstanding company: Georg Fischer.

What you can expect:
You will work in teams on specific high priority assignments that flow from the company. Delving into the assignments you will both contribute to solving strategic issues and have an impact on their implementation at the company.

To gain insight into the company and its culture you will receive briefings from senior management, conduct interviews with experts and run workshops with your case managers. In the final presentations you will pitch your findings to key stakeholders and top management representatives and receive valuable feedback.

Furthermore you will be coached and supported by MTEC professors on the topics of project scoping, problem definition and solving, process improvement, strategy and board presentation.

The course is directed and organised by PD Dr. Zeynep Erden and Dr. Isabel Spicker as part of the MTEC Leadership Development Programme.

What we expect from you:
You are an ambitious ETH student or doctoral candidate who is looking for a rewarding learning opportunity and is eager to go the extra mile. You will work on a real case study of strategy, technology and innovation in close collaboration with the senior management of an outstanding Swiss company. The recommendations that you formulate in collaboration with members of your team as well as with internal and external experts will be discussed at the Partner and Director levels. This demands a deep understanding of the company’s leadership culture.

In this endeavour you are coached and supported by
- Stefano Brusoni, Chair of Technology and Innovation Management
- Georg von Krogh, Chair of Strategic Management and Innovation
- Torbjorn Netland, Chair of Production and Operations Management
- Zeynep Erden, Vlerick Business School/ D-MTEC

Literature
Literature and readings will be announced in the coaching sessions.

Prerequisites / notice
Please apply for this course via the official website (www.mtec.ethz.ch). Apply no later than August 22.

The number of participants is limited to 18.

ECTS: 4
Participates receive a certificate.

363-0404-00L
Industry and Competitive Analysis
Due to didactic reasons originating from the group-work based approach, the number of participants is limited to 30. First come first served by order of enrollment in myStudies.

Experience in statistical analysis with tools such as SPSS or equivalents is an advantage.

Abstract
Industry and Competitive Analysis (ICA) is a part of any strategy development. It contains a very practical set of methods to quickly obtain a good grasp of an industry. The purpose of ICA is to understand factors that impact on the financial performance of the industry, and as well the financial performance of firms within the industry.
This course is built upon a management classic (Competitive Strategy: Techniques for Analyzing Industries and Competitors by Porter, 1980). You will learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop your own research project. The successful completion of the course will help you to:

- Plan and manage your thesis project
- Structure your manuscript
- Design your research and choose an appropriate methodology for analysis (specific research methods and techniques are not discussed in this course)
- Develop and frame interesting and relevant research questions and problem statements
- Think critically and make compelling arguments about the strengths and weaknesses of published management research
- Find review appropriate literature and previous research for your thesis
- Structure your manuscript
- Plan and manage your thesis project

Student competencies that will be developed in this course include:

- Industry and competitive analysis (ICA) is a part of any strategy development in firms and other organizations. It contains a very practical set of methods to quickly obtain a good grasp of an industry, be it pharmaceuticals, information and communication technology, aluminum, or even the beer industry. The purpose of ICA is to understand factors that influence the performance of the industry, and as well the performance of firms within the industry.
- As the world has witnessed tremendous development in digital technologies, many industries are in the midst of transitioning from analogue to digital business model. Digitalization is radically changing what companies produce and way companies are run. We need a new understanding of industries and a more advanced set of analytical tools to adapt to these changes. That is why we have developed our course as ICA 2.0, which will provide an updated picture of various industries and tools for analyzing them before and after digital transformation. In this course, we will study theoretical frameworks, examine evidence from empirical research, and benefit from the experiences shared by guest speakers.

The course is organized as a combination of lectures, case studies, and tutored group work involving the selection and analysis of industries, analysis and development of strategies for selected competitors, and presentation of results.

Grades:
50% paper/industry report (group)
50% final presentation (group)

Literature
This course is built upon a management classic (Competitive Strategy: Techniques for Analyzing Industries and Competitors by Porter, 1980). More recent research findings and practitioner-oriented papers in the area of strategy are also included. Readings associated with each lecture should be done before the lecture day. To access the journal articles listed below, you have to be within the ETH domain (either directly connected to the ETH network within ETH or using VPN). PDF versions of the Harvard Business Review articles are only available via the class Moodle.

Competitive strategy
- Chapter 2 of Porter (2004)
- Case study: Southwest Airlines

Industry Dynamics
- Chapter 3 of Porter (2004)
- Case study: Southwest Airlines

Strategic groups & firm membership

ICA in the Digital Age

Case study: Southwest Airlines

Chapter 2 of Porter (2004)

Analysis of industries

Students develop an understanding of how the structure of industries impact on firm and industry-level performance

- Students get familiar with, and obtain practical skills in analyzing industries and firms within them.
- Students develop a broad understanding of the impact of digitalization on various industries and develop an in-depth understanding of (at least) one chosen industry
- Students improve analytical skills needed to successfully compete in the digital age

Prerequisites / notice
Due to intensity of the tutoring format, the number of students is limited to 30 participants. Students will be accepted according to the order of enrollment in myStudies. Exchange students can register by sending e-mail to evilar@ethz.ch. If facing problems with registration to myStudies, registration will be handled individually, case by case. E-mails that are sent before the starting date of registration to myStudies will not be accepted.

An electronic confirmation of the registration will be sent out shortly before the start of the semester, which contains an access link to the Moodle-Website of the course (readings, resources for group works, group assignment)

Note that class participation is important. Students should judge if full commitment can be made to attending the lectures before registration.

Management Research

Participation in both sessions and completion of all assignments is required to receive the credit.

This course requires preparation time and completion of an assignment before the first course day. Please check the Moodle course page for more information.

Abstract
Students learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop their own research projects.

Objective
You will learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop your own research project. The successful completion of the course will help you to:

- Think critically and make compelling arguments about the strengths and weaknesses of published management research
- Find and review appropriate literature and previous research for your thesis
- Develop and frame interesting and relevant research questions and problem statements
- Design your research and choose an appropriate methodology for analysis (specific research methods and techniques are not discussed in this course)
- Structure your manuscript
- Plan and manage your thesis project

363-0887-00L

Management Research

W 1 credit 1S

N. Geilinger

Autumn Semester 2021
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This course combines lectures, group discussions and individual assignments.

Day 1: Course introduction, group analysis exercises and discussions, lectures on main topics.

Between course days 1 and 2: Individual and group work on assignments.

Day 2: Assignment review and discussion, lectures on main topics, conclusion session.

Target audience:
The course is designed with two groups of students in mind: first, students who write their master thesis at the SMI chair and second, students who write their master thesis in the field of management at other MTEC chairs.

For both groups, the focal topics of this course will arise frequently during the journey of writing their thesis, and the majority of topics are relevant for all students. However, we will provide some specific content (grading guidelines, thesis format) which might not be applicable for students tutored at other MTEC chairs.

Course topics:
1. Thesis topic and thesis proposal:
   - Choice of thesis topic, identification of research gap, formulation of research questions, writing of thesis proposal

2. Literature review:
   - Search and evaluation of academic literature, use of reference tools, writing of theoretical background chapter of thesis

3. Empirical research design:
   - Types of empirical research designs, choice of methodology, overview of data collection and analysis methods

4. Research output and report:
   - Writing of introduction, results and conclusion, thesis format and structure

5. Thesis assessment:
   - SMI grading criteria, MTEC guidelines

References:

Prerequisites / notice
This course is for all students who write their master thesis at the Department of Management, Technology, and Economics.

The course is required for all M.Sc. students and MAS students who write their master thesis at the Chair of Strategic Management and Innovation.

The course is graded based on the assignments, peer feedback, and participation in group discussions.

The first assignment is due before the first course day. Please check the assignments on the Moodle coursepage. If you sign up for the course on short notice before the first course day, please advise the lecturer of your registration by email.

Supply Chain and Information Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-0425-00L</td>
<td>Transformation: Corporate Development and IT</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>T. Gutzwiller</td>
</tr>
</tbody>
</table>

Abstract
The lecture treats the main challenges of business transformation and the alignment of corporate development and IT activities. It presents a holistic approach to business transformation projects by introducing an integrated model dealing with three main design areas “strategy”, “processes” and “information systems” and applying this model to various case studies.

Objective
The goal of the lecture is to understand the main challenges of corporate transformation and to demonstrate the application of a holistic project procedure model for corporate transformation projects with special emphasis on the alignment of business and IT.

The student should understand and be able to explain

the main reasons for corporate transformation,
the relevant management processes to manage corporate transformation,
the interdependencies between strategy, processes and information systems, especially how this three levels interrelate,
the critical success factors for the successful accomplishment of large scale corporate transformation projects,
the main instruments of project, quality and change management and
the different types of resulting IT projects.

Content
The globalization of the world leads to an increasingly faster pace in business transformation. Enterprises have to adapt faster and even faster to the environmental changes in a global economy to remain competitive and to make sure they stay in business. In todays information age this does not only mean to adapt business strategy and business processes but also to adapt information systems to the new circumstances. The fast adaptation trough large scale corporate transformation projects that change strategy, business processes and information systems is critical to ensure competitiveness for tomorrow. The introduction of new business processes and information systems typically takes years in very complex large scale projects. Many projects fail because of insufficient alignment between decision makers in business and IT. Unclear understanding of the overall project scope, undefined roles and responsibilities, unclear project processes, quality problems and resistance to change are some typical problems found in such projects. The lecture is subdivided into following modules:

Corporate development introduction and motivation,
Parallelization of corporate development and complexity reduction,
Planning process and project portfolio management in corporate development,
Management of large scale projects integration of strategy, processes and information systems,
Quality management in large scale projects,
Project management in large scale projects,
Change management within projects. The lecture is accompanied by four case studies that are used to exemplify the contents of the lecture by applying the concepts to real situations in corporate life.

<table>
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<tr>
<th>Number</th>
<th>Digital Health Project</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>363-1135-00L</td>
<td>Digital Health Project</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>T. Kowatsch</td>
</tr>
</tbody>
</table>

Abstract
Today, we face the challenge of chronic conditions. Personal coaching approaches are neither scalable nor financially sustainable. The question arises therefore to which degree Digital Health Interventions (DHIs) are appropriate to address this challenge. In this lecture, students will learn about the need for, as well as the design, implementation and assessment of DHIs.
The increasing prevalence of chronic conditions leads to the important question of how to develop evidence-based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, information systems research, computer science, and behavioral medicine, this lecture has the objective to help students and upcoming healthcare executives interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs. After the course, students will be able to...

1. understand the importance of DHIs for the management of chronic conditions
2. discuss the opportunities and challenges related to DHIs
3. better understand the design, implementation and evaluation of smartphone-based and chatbot-delivered DHIs.

Today, we face the challenge of dealing with the specific characteristics of chronic conditions. These are now responsible for around 70% of all deaths worldwide and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. Chronic conditions require an intervention paradigm that focuses on prevention and lifestyle change. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socioeconomic influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

Against this background, the question arises on how to develop evidence-based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, information systems research, computer science, and behavioral medicine, this lecture has the objective to help students and upcoming healthcare executives interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs. After the course, students will be able to...

1. understand the importance of DHIs for the management of chronic conditions
2. discuss the opportunities and challenges related to DHIs
3. better understand the design, implementation and evaluation of smartphone-based and chatbot-delivered DHIs.

To reach the learning objectives, students will work on the following topics:

1. Motivation for Digital Health
   - The rise of chronic diseases in developed countries
   - Lifestyle as medicine and prevention of chronic diseases
2. Design of a Digital Health Intervention (DHI)
   - Overview of design frameworks for health interventions
   - Development of a conceptual model for a DHI
   - Implementation of a smartphone-based and chatbot-delivered DHI
3. Evaluation of DHIs
   - Overview of evaluation methods and evaluation criteria for DHIs
   - Evaluation of a smartphone-based and chatbot-delivered DHI

Course structure
The lecture is structured in two parts and follows the concept of a blended treatment consisting of online-based self-learning sessions and complementary “support” sessions via Zoom. In the first part, students will learn about the topics of the three learning modules in weekly online sessions. Complementary learning material (e.g., video clips), multiple-choice questions, and exercises are provided online via Moodle. In the second part, students work in teams and will use their knowledge from the first part to develop a smartphone-based and chatbot-delivered health intervention with MobileCoach (www.mobile-coach.eu), an open-source software platform for digital interventions and ecological momentary assessments. Each team will then present and discuss their resulting digital health intervention and evaluation results with their fellow students who will provide peer-reviews. Additional online coaching sessions are offered to support the teams with the design and evaluation of their digital health intervention, and with the preparation of their presentations.

Literature

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management assessed

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Production and Operations Management – Supplement Credit

**363-0445-02L**

**Title:** Production and Operations Management – Supplement Credit

**Type:** W

**ECTS:** 1 credit

**Hours:** 1A

**Lecturer:** T. Netland

* Does not take place this semester.

*A parallel enrollment to the lecture 363-0445-00L Production and Operations Management is mandatory.*

**Abstract:**
Extension to course 363-0445-00 Production and Operations Management.

**Objective:**
- This course strengthens the learning objectives of the POM core course (see separate syllabus). After completing this course,
  - students can use lean thinking to improve the productivity of production processes,
  - students can conduct fundamental process mapping analyses,
  - students can select and implement many lean production techniques,
  - students can select and use problem-solving tools and methods, and
  - students understand the role of management in manufacturing.

**Content:**
This course is an extension to the course 363-0445-00 Production and Operations Management. Participants get an extra deep dive into key concepts of POM.

The lectures in this course are highly interactive. To pass this course, students need to complete a course assignment in pairs. The course assignment consists of two parts: preparations for the lecture and a reflection essay after the lecture.

**Prerequisites / notice:**
This course (1ECTS) is offered as an extension to the D-MTEC core course 363-0445-02 Production and Operations Management (3 ECTS). To take this course, you have to follow the core course.

Due to its practical format, this course is limited to ca 30 students. Note that we offer this course primarily for students who need the extra credit (total of 4 ECTS) to complete their study plans. This will typically be students from D-MAVT and, in some cases, exchange students. Students from all other departments (including D-MTEC) are welcome to apply to the lecturer. If capacity, applicants may receive written acceptance by the teaching team to join.

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**Systems Design and Risks**

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<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>363-1162-00L</td>
<td>Resilience in the New Age of Risk</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>H. Schernberg, C. Hölscher, J. Jörin, G. Sansavini</td>
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</tbody>
</table>

* With the global increase in interconnectivity, the potential for disruption is everywhere. Modern organisations who build resilience in all systems will respond intelligently to emergent disruptions. This course explores the concept of resilience and its application to socio-technical systems: The resilience of infrastructure systems and how individuals and social groups interact in and with them.

**Objective:**
After taking this course, you will be able to:
- Discuss the concept of resilience and related frameworks and concepts, and explain their relevance in different contexts (organizations, infrastructure, social groups...).
- Use and discuss key resilience metrics and use them to analyze infrastructure systems.
- Discuss the role of organizational resilience and describe methods to improve it.
- Describe how resilience is applied in practice.
Our increasingly complex and connected systems face continuously emerging disruptions. Resilience constitutes a fundamental departure from the philosophy of risk-management. With resilience, stakeholders adopt risk mitigation strategies aligned to the theories of complex systems.

It is, however, difficult to learn about resilience, since it applies to an extremely large array of systems and contexts. Moreover, the topic of resilience is surprisingly absent from most university curricula. This course fills a gap and walks you through a mode of thinking that is bound to shape the way risks and disasters are dealt with in our increasingly connected society. Hence, tomorrow's risk managers will and shall also be "resilience managers".

This course breaks down the concept of complex systems and their resilience. It introduces some of the different flavors of resilience and provides tools for building it in various socially relevant areas (social resilience, engineered systems resilience, organizational resilience...).

The course is divided in 4 parts.
- Part 1: Foundations of Resilience (4 hours)
- Part 2: Resilience Analysis: Infrastructure Systems (10 hours)
- Part 3: Organizational resilience and sensemaking (6 hours)
- Part 4: Resilience in Practice (4 hours)

Part 1 introduces the concept of resilience, and the framework in which it is applied. The distinction between resilience and risk management is highlighted, as well as how these approaches complement each other. The founding concepts of resilience are explained and illustrated: vulnerability, disruption, absorption, recovery, adaptation, etc.

Part 2 walks you through the analysis of the resilience of infrastructure systems. It introduces the useful metrics of resilience. It provides examples of building resilience into complex systems, by increasing the robustness and recoverability of systems, and reducing vulnerabilities. Finally, students will explore the optimization of infrastructure systems.

Part 3. Every system subject to potential disruptions is managed by a human organization. Sensemaking describes how humans frame the problem. It is a process whereby organizational actors attach meaning to external events to resolve the uncertainty surrounding them. Investing in mindfulness improves personal and organizational resilience and success. Finally, the management of organizational resilience is discussed.

Part 4 will provide examples of the use of resilience by practitioners, with guest speakers from the public and private sector.

This course is aimed at MSc and MAS students, from MTEC and other departments. Ideally, students have a quantitative background and some knowledge of risk management.

The Science and Practice of Resilience, Book by Benjamin D. Trump and Igor Linkov

The course is hybrid (in-person or remote).

Literature

<table>
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<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>Taught competencies</td>
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<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Decision-making</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>not assessed</td>
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<td></td>
<td>Project Management</td>
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</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
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</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Self-presentation and Social Influences</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
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<td>not assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
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Economic Dynamics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>363-1137-00L</td>
<td>Applied Econometrics in Environmental and Energy Economics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>D. Cerruti, N. Kumar, S. Srinivasan</td>
</tr>
</tbody>
</table>

It is highly recommended to take 363-0570-00L Principles of Econometrics first.

Number of participants limited to 40.

Abstract

The course introduces to the most common empirical methods for the analysis of issues in environmental, energy, and resource economics. The course includes computer laboratory sessions, and covers the following broad topics: demand models, discrete choice models, empirical methods in policy evaluation, field- and quasi-experiments.

Objective

At the end of the course, the students will be able to: understand the most common empirical methodologies used in environmental, energy, and resource economics; understand the problems the methodologies learnt in class aim to address; appreciate the importance of causal inference in empirical economics; read and understand the research papers in the literature; apply the empirical methods learnt in class using the software R.
Content

The course introduces students to empirical statistical methods that have wide application in environmental, energy, and resource economics and it is divided in four blocks. The first block is a quick review of the basic econometric methodology and concepts (OLS, standard errors, logit/probit models); the second block introduces demand models like the Almost Ideal Demand System, discrete choice models, and their evolutions; the third block explores causal inference in empirical economics and the main reduced-form econometric techniques used in policy evaluation, such as difference-in-differences, regression discontinuity and synthetic control; the fourth block introduces field experiments and instrumental variables, and their characteristics.

At the end of each block there will be a computer laboratory class in which the student will learn to apply the methodologies learnt in class using the statistical open-source software R. Throughout the course, students will have the chance to work on actual data used for analysis in economics papers.

The lectures will make use of current research papers in the literature to illustrate practical examples in which the methodologies learnt in class have been used. Students will be expected to read in advance the paper that will be explained during the lecture.

The evaluation policy has the aim to allow students to get practical experience on the econometric methodologies learnt in class. Thus, beyond a final computer exercise exam (60% of the grade), the course includes short takehome computer exercises (40% of the grade).

As the course will be centered on econometric methods, it is recommended that students have taken 363-0570-00L Principles of Econometrics first, or have otherwise a solid knowledge of basic econometric methodologies as detailed in Part 1 of Wooldridge, Jeffrey M. (2018) Introductory Econometrics : A Modern Approach. Seventh ed. ISBN: 978-1-337-55886-0. Knowledge of statistical software R is helpful, but not required and will be taught in the computer laboratory sessions.

It is highly recommended to take 363-0570-00L Principles of Econometrics first.

Prerequisites / notice

363-1136-00L Dynamic Macroeconomics, Innovation and Growth W 3 credits 2V H. Gersbach

Students who have successfully completed the course “Dynamic Macroeconomics” (364-0559-00L) or “Economics of Innovation and Growth” (363-0562-01L) can not register for this course.

Abstract

Introducing dynamic models and workhorses in macroeconomics, understanding the role of innovation and institutions for economic development and discussing policies to foster innovation and economic growth, with a perspective on how digitization and artificial intelligence will affect our economies.

Objective

After the course, students will be familiar with dynamic general equilibrium theory and the basic workhorses in macroeconomics. Participants will be able to speak the Arrow-Debreu and recursive language and apply the frameworks to interesting issues, such as innovation and growth. Moreover, students will understand how the world has developed over the last centuries and the proximate and fundamental causes of innovation and economic growth. Students will understand and apply the basic models of economic growth and will be able to identify policies to foster innovation and growth and to reduce the large wealth differences in the world. Finally, they understand how digitization and artificial intelligence will drive the economies.

Content

1. Introduction

2. The Arrow-Debreu Approach and Sequential Markets

3. The Neoclassical Growth Model and the Representative Agent Model (with Mathematical Background)

4. Technological Progress and how the World has developed

5. Innovations and Growth (New Growth Theory)

6. Growth Policies and Fundamental Causes for Growth

7. Digitization and Artificial Intelligence

Literature


14. Current Literature on Digitization and Artificial Intelligence

Prerequisites / notice

Economics by its Nobel Prizes W 3 credits 2V A. Fabre

Who are the 86 laureates of the economics “Nobel prize”, and what are their scientific contributions? This course will present the major concepts, theories and results in modern economics, through an overview of the work of a selection of economics “Nobel prize” as well as Leontief prize laureates.
Objective
- Have an overview of the discipline of economics in all its diversity.
- Know the main school of thoughts in economics, such as Keynesian, neoclassical and neokevynesian macroeconomics, behaviorism, institutionalism, empiricism.
- Understand major concepts of various fields within economics such as macroeconomics, microeconomics, public economics, econometrics. These concepts include (but are not restricted to): preferences, utility, social welfare, discounting, factors of production and their marginal products, potential output, the paradox of thrift, the Phillips curve, the natural interest rate, rational expectations, Nash equilibrium, incentive-compatibility, Pigouvian taxes, asymmetry of information, market efficiency, market imperfections, the equity-efficiency trade-off, risk aversion, loss aversion, capabilities, common goods, endogeneity, instrumental variable.
- Name major post-war economists, talk about their main contributions, and situate them in the history of economic thought.
- Be able to have a critical understanding of some articles in journals like the Financial Times, and to skim-read peer-reviewed articles in economics.

Content
- Target group: The course will be open to master students as well as PhD students. There is no prerequisite apart from being curious about economics and the society.
- Relevance: As the content of the course is voluntary broad, the course will teach concepts relevant for many different types of interests. Indeed, economics is connected to various other domains (politics, finance, management, statistics, psychology...) and concepts from economics may be applied in a variety of contexts. Besides, the course will help students think about important contemporary issues (public debt, fairness of the tax redistribution, the role of government, climate change...). More generally, the course will be valuable for the students' general culture.
- Outline: Each lesson will present the theories, concepts and results introduced by a few major economists, grouped by theme and school of thought, and loosely following a chronological order. About half of economics "Nobel prize" laureates will be presented, as well as several recipients of the Leontief prize (an annual award to outstanding economists whose research addresses contemporary realities and support just and sustainable societies"). The fourteen lessons will cover: Keynesianism; libertarianism; neoclassical macro; neokevynesian macro; foundations of micro; game theory; behavioral micro; micro of organizations and contracts; public economics; econometrics; finance; economics and society (i.e. institutions, development, well-being, environment); development (through Leontief prize winners); macroeconomics (also Leontief).
- Expectations: Students are expected to retain two to three key concepts in each lesson. Readings between the lessons will help them to do so. Students will also have to read, digest, and situate an entire book or peer-reviewed economics article.
- Course assessments: Some lessons might begin with pop quizzes to check whether students have integrated key concepts of the previous lessons. Assessment may also include an individual essay or a presentation. This will consist of a contextualised summary of a highly cited economics writing (article or book), preferably from an economist studied in class. By dispensation, this final work could instead deal with several writings (instead of one), or describe a specific approach, theory or controversy in economics.
- References (for an updated list, go to sites.google.com/view/adrien-fabre/teaching):
  - Dostaler, Gilles, Econometrics, Analysis and Dictionary of Major Economists, (Routledge, 2005)
  - Karier, Tom, Intellectual Capital: Forty Years of the Nobel Prize in Economics (Cambridge University Press, 2010)
  - Voyer, Michel, A History of Macroeconomics from Keynes to Lucas and Beyond (Cambridge University Press, 2016)

363-1037-00L Fiscal Competition and Multinational Firms W 3 credits 2V M. Köthenbürger, M. Stimmelmayr

Abstract
The course enables students to understand how multinational firms respond to differential tax regimes in a global economy and how countries strategically use the tax system to host multinationals. In particular, the course covers transfer pricing issues, internal financing decisions and agency problems and their role in a tax policy.

Objective
- Understanding how taxes influence decisions of multinational firms
- Develop thinking about the strategic use of differential tax systems for multinational firms
- Evaluate options for governments to respond to the tax planning behavior of multinational firms

Content
- Using theoretical models and empirical analysis to uncover regularities in how multinational firms respond to taxes
- Multinational firms have grown in importance in recent decades. Given that their affiliates are located in different countries, they face various tax systems. This creates complexity with respect to the operation of a multinational and also offers the option to benefit from differences across various tax provisions. Starting from this observation, the course looks at how multinational firms respond to the differences in tax provisions and how governments respond to this behavior in their choice of tax systems. Different channels how multinational firms allocate taxable profits across countries will be analyzed: transfer pricing policies, internal financing decisions and investments. A particular emphasis will be put on how agency problems within multinational firms interact with tax avoidance behavior and how they are related to tax policy.

The course has two parts: The first part of the lecture contains a detailed treatment of the different channels multinational firms can use to strategically allocate profits to low-tax countries and how the tax avoidance decision might interfere with other decisions of the multinational firm. Building on this insight, we will discuss whether governments might strategically choose to adjust its tax provisions either to benefit from the multinational firm tax-saving behavior or to protect its tax base against the tax-planning behavior. In the second part of the course, we will discuss different papers that empirically analyze the validity of the different channels we have discussed in the first part. Students select one paper out of a list of papers (to be distributed in the course) and give a short presentation of the paper (max. 30 minutes). Afterwards, we will enter a discussion of the presented paper and clarify unaddressed issues.

363-1027-00L Introduction to Health Economics and Policy W 2 credits 1V C. Waibel

Abstract
Health expenditures constitute about 10% of GDP in OECD countries. Extensive government intervention is a typical feature in health markets. Risk factors to health have been changing with growing importance of lifestyle factors such as smoking, obesity and lack of physical activity. This course gives an introduction to the economic concepts and empirical findings in health economics.

Objective
Introduce students without prior economic background to the main concepts of health economics and policy to enhance students understanding of how health care institutions and markets function.

Content
Please note that we will apply basic economic concepts to health care markets. Hence, master students with an economic background have to expect that a large share of the concepts will overlap with their previous courses. However, they are, of course, welcome to join the course.

The course gives an introduction to the economic concepts and empirical findings in health economics to enhance students understanding of how health care institutions and markets function. Motivated by the fact that health care markets are designed differently across countries, this course looks at the challenges in regulating health care markets. First, two important decisions of individuals will be analyzed: What types and amount of personal health care services does an individual demand? How much will health insurance coverage be purchased? In the second part, the supply side of health care markets will be discussed. What is the financial incentives of physicians, and how do these influence physicians' treatment choices? What does it mean and imply that a physician is an agent for a patient? The choices made by societies about how health care services are financed and about the types of organizations that supply health care will be addressed in the third part. One important choice is whether a country will rely on public financing of personal health care services or encourage private health insurance markets. How could and should public health insurance be designed? The advantages and disadvantages of the alternatives will be discussed to provide a framework for analyzing specific types of health care systems.
The course covers the following topics:

01 Welcome and course logistic; Introduction to decision theory

By the end of the course, students will be able to:

- How will the overall economy develop during the next quarters and years? What is the impact of the exchange rate on economic activity?

The Economics of Societal Decisions under Risk

3 credits

2V
to be announced

S. Sarfaraz

Societal decisions often involve risk: Should a new drug or pesticide be approved, given the unknown side-effects to human health and the environment? What principles should guide such decisions? This course provides the theoretical toolkit (in particular Cost-Benefit Analysis) for societal decision-making under risk and contrasts theoretical recommendation with the actual regulatory practice.

Prerequisites:

- Principles of Macroeconomics
- Principles of Econometrics

During computer exercises, we utilize the time series models to study real world examples using R.

363-1161-00L

Time Series Econometrics and Macroeconomic Forecasting

W 3 credits 2V

S. Sarfaraz

This course introduces the methods for analyzing and forecasting macroeconomic activity using multivariate time series analysis. We will study econometric models that central banks, government agencies and other research institutions use to analyze and forecasts macroeconomic variables.

Objective

How will the overall economy develop during the next quarters and years? What is the impact of the exchange rate on economic activity and inflation? How should we derive macroeconomic scenarios under alternative assumptions about the evolution of key variables like oil prices, exchange rates or the world economic activity? What are the effects of changes in monetary policy, fiscal policy or COVID-19 on economic activity? After completing this course, students will be able to tackle these and related questions using multivariate time series methods as applied by researchers and professional forecasters.

Content

The course covers the following topics:

- Vector autoregressive (VAR) models
- Identification of macroeconomic shocks
- Conditional forecasting (macroeconomic scenario analysis)
- State space models
- Macroeconomics and Big Data

During computer exercises, we utilize the time series models to study real world examples using R.

Prerequisites:

- Principles of Macroeconomics
- Principles of Econometrics

363-1124-00L

The Economics of Societal Decisions under Risk

W 3 credits 2V
to be announced

S. Sarfaraz

Does not take place this semester.

Societal decisions often involve risk: Should a new drug or pesticide be approved, given the unknown side-effects to human health and the environment? What principles should guide such decisions? This course provides the theoretical toolkit (in particular Cost-Benefit Analysis) for societal decision-making under risk and contrasts theoretical recommendation with the actual regulatory practice.

Objective

By the end of the course, students will be able to:

1. Name the building blocks of cost-benefit analysis under risk
2. Describe the connections and differences between welfare economics under uncertainty and cost-benefit analysis under risk
3. List real-world examples of risk regulation and explain differences between practice and theoretical recommendation
4. Analyze real-world risk-regulatory problems by breaking them up into relevant components
5. Select an appropriate framework for evaluating stylized risk regulatory tasks
6. Prepare a well-founded and comprehensive recommendation and discuss limitations and robustness

In addition to these course-specific learning objectives, students shall also develop their skills in:

1. Working successfully in a team: Agree on a topic for a joint project, execute the project together, and prepare a joint report
2. Convey complex information succinctly and effectively in a written report
3. Provide fellow students with useful feedback on their work

Content

01 Welcome and course logistic; Introduction to decision theory
- The Precautionary Principle: Basic narrative and context
- Reality of Risk Management: Pesticide regulation
- Reality of Risk Regulation: Violation of the equimarginal principle
- Uncertainty in CBA: the dominant, naive approach
- Risk Assessment in Practice
- Value of Learning: sequential models of risk regulation
- Risk assessment: compatible with models of value of learning?
- Option price and option value: Theory
- Option price and option value: Practice
- Uncertainty and the social discount rate
- Discounting in the real world
- Midterm Quiz: Discuss which tool they use
- Welfare economics: utilitarianism and ex-ante egalitarianism
- Risk economics: the long way from theory to practice
- Risk-risk trade-off: theory and practice
- [Some time allocated to student projects]
- Welfare economics beyond risk: ambiguity and alternatives
- Limitations of CBA: Climate Risk and fat tails
- Political Economy of Risk Regulation: Actors and Incentives
- [Some time allocated to student projects]
- International Dimension of Risk Regulation
- The reality of precaution
- Project Presentations
- Wrap-up and outlook

Lecture notes
n/a

Literature

The lecture provides an introduction to some of the central issues in labor economics, including the determinants of labor supply, firms' hiring decisions, and the impact of immigration on resident wages and employment? Is there wage and hiring discrimination against women, men, and foreigners in the labor market? What are its effects? What drives the surge in wage inequality in developed countries in the last decades? What are the effects of globalizations on wages and employment? What are the implications of a universal basic income for labor supply and demand? Are employment policies effective in reducing unemployment? Is a higher minimum wage always detrimental to employment? Do children in large families work less if they have a universal (guaranteed) income or pay higher taxes? How does a firm determine its employment? Does a minimum wage increase employment or reduce it? How does a firm determine its wages? Do unions have an impact on wages? Is the labor market segmented by gender and ethnicity? What are the causes of wage inequality? What are the advantages and disadvantages of different labor market policies? Are there labor market imperfections? How do labor market policies affect the labor market?

After presenting how modern labor economics conceptualizes these issues, the course discusses state-of-the-art empirical research papers on these issues and discusses the empirical challenges related to their research design. Students will learn how empirical papers that answer these questions. In the context of the topics, the course thus provides an introduction to basic statistical methods and data analysis techniques, including regression analysis and quasi-experimental methods. Students will also learn how empirical researchers use big data to get from correlations to causality. This introduction to modern applied economics does not require any prior knowledge of econometrics or statistics. Students will be able to apply the concepts of econometrics, such as regression analysis, to real-world problems. They should be able to read and understand regression output tables. Additionally, students will be able to apply the estimation approaches in practice using STATA.

For the theoretical portions of the lectures, we will prepare slides for in-class discussion. Slides will be distributed electronically before each lecture. For the applied portion of the lectures, we will provide STATA do files, log files, and data sets. Problem sets will also be made available after every lecture. These problem sets will not be collected or graded, but students can use them in order to prepare for the final exam. Solutions will be made available in the following lecture.

While there is no required textbook for the course, we draw from the following texts, which are also recommend for the preparation of the exam:


### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |

### Literature

The main aim of this course is to analyse the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy and the differences between monetary policy rules and discretionary policy. It will also make connections between theoretical economic concepts and current real world issues.

This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

The course will be based on chapters of:

- G. Loumeau
- C. Daminato

At the end of the course, students will be able to:

- understand the basic economic aspects related to population aging;
- explain the structure and functioning of public and private pension systems, and analyze related issues of insurance and incentives;
- understand the mechanisms through which the demographic transition challenges the provision of pensions, and discuss reform options;
- understand the key theoretical tools used in household finance to analyze the behavior of individuals over their life-cycle;
- understand how the most common empirical methods in program evaluation are used to causally identify the effects of pension policies;
- analyze and critically discuss policy-relevant questions about individual savings and retirement behavior.

The third part of the course presents and discusses recent empirical evidence from research papers on how individuals save, invest their wealth and plan for retirement, the role of social security and the effects of pension policies. Topics include: the relation between social security wealth and private wealth, the effect of retirement saving incentives on individual behavior, the effect of pension reforms, longevity risk and annuities, the importance of financial knowledge for retirement planning. The lectures offer an introduction to the quantitative methods used to analyze these issues, such as basic model simulation techniques and econometric methods for policy evaluation.

No formal prerequisites. The assessment policy is designed to allow students to apply the concepts and methods learnt in class to real-world issues. The assessment will be based on the critical presentation (35%) of one country's pension system and a final project (65%), in which students may apply the relevant methods to analyze topical questions related to issues in the economics of aging, pensions and savings.

Basic knowledge in international economics and a good background in macroeconomics.
The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong microfoundations and allow for precise policy recommendations.

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### 363-1107-00L Workshop & Lecture Series on the Law & Economics

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<tr>
<th>Course title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

### Abstract

Finding and retaining talent for companies is becoming increasingly important nowadays. While Switzerland has a comparatively efficient labor-market-oriented education system, other countries find it more challenging to develop the skills needed by the labor market. We will consider contributions of economics and other social sciences to understanding outcomes of education and training systems.

### Objective

Using internationally comparable data, students can measure, compare and assess the human capital performance of education systems.

Students can use case studies to identify and evaluate the different institutional features of labor-market-oriented education systems, and use those features to explain certain outcome effects on the youth labor market.

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### 851-0735-09L Workshop & Lecture Series on the Law & Economics

<table>
<thead>
<tr>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>Workshop &amp; Lecture Series on the Law &amp; Economics of Innovation</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>S. Bechtold, H. Gersbach</td>
</tr>
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### Abstract

This series is a joint project by ETH Zurich and the Universities of St. Gallen and Zurich. It provides an overview of interdisciplinary research on intellectual property, innovation, antitrust, privacy & technology policy. Scholars from law, economics, management and related fields present their current research. All speakers are internationally well-known experts from Europe, the U.S. & beyond.

### Objective

After the workshop and lecture series, participants should be acquainted with interdisciplinary approaches towards intellectual property, innovation, antitrust, privacy and technology policy research. They should also have an overview of current topics of international research in these areas.

### Content

The workshop and lecture series will present a mix of speakers who represent the wide range of current social science research methods applied to intellectual property, innovation, antitrust, privacy and technology policy issues. In particular, theoretical models, empirical and experimental research as well as legal research methods will be represented.

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### Taught competencies

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories: assessed
- **Domain B - Method-specific Competencies**
  - Analytical Competencies: assessed
  - Problem-solving: assessed
- **Domain C - Social Competencies**
  - Communication: assessed
- **Domain D - Personal Competencies**
  - Creative Thinking: assessed
  - Critical Thinking: assessed

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### Human and Entrepreneurial Behaviour

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<th>Number</th>
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<th>Type</th>
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<tbody>
<tr>
<td>363-1044-00L</td>
<td>Applied Negotiation Seminar</td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>A. Knobel</td>
</tr>
</tbody>
</table>

Prerequisites: Successful completion of lectures "363-1039-00L Introduction to Negotiation".

### Abstract

The block-seminar combines lectures introducing negotiation and negotiation engineering with the respective application through in-class negotiation case studies and games.
Objective

- learn more theory of negotiation and apply this learning in simulated negotiations
- have their perceptions of rationality, fairness and trust challenged through little embedded experiments
- learn to recognize and analyze negotiation contexts and interests and generate creative solutions
- learn to negotiate under pressure (with time and mandate restrictions) and experience (and potentially chair) a formal negotiation
- learn to read, analyze and present a scholarly paper

Content

This block seminar is an extension of the course "Introduction to Negotiation" and provides more detailed insight into key aspects of the field of negotiation and negotiation engineering.

In particular,

- a series of brief lectures will outline foundational aspects of negotiation science, such as rationality, fairness, and trust, as well as the possible application of machine learning in negotiation
- three practitioners will describe lessons learnt in their negotiation domains (diplomacy, labor, and business) and allow time for Q&A and discussion
- Professor Ambühl will elucidate further current cases from his professional experience
- students will apply course input in a number of challenging simulations (ranging from simple 30 minute games to full-fledged international ten party negotiations). In each game they will be asked to represent a party and negotiate as skillfully as they possibly can within the constraints of their mandate
- each student will be assigned a scholarly paper (20 to 30 pages) between the two blocks to read. They will give a 20 minute group presentation with one or two of their peers and submit a brief reflection report after the seminar

The course size is deliberately limited (30 maximum) to enable ample opportunity to interact with the lecturers, guests and each other.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Authors</th>
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<tbody>
<tr>
<td>363-1082-00L</td>
<td>Enabling Entrepreneurship: From Science to Startup</td>
<td>3</td>
<td>2V</td>
<td>A. Sethi</td>
</tr>
</tbody>
</table>

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 40. It is preferable that the students already form teams of at least two persons, where both the team-members would like to do the course. The names of the team-members should be provided together with the business idea or the motivation letter submitted by the students.

The students should submit the necessary information until September 13 and apply to anilsethi@ethz.ch

Abstract

This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective

Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs
2. The students can be from business or science & technology
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea

Content

The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It is important for a startup to recognize its needs and find the investors that fit these needs and are best aligned with the vision of the founders
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay
8. Legal overview, company forms and shareholders’ agreements (including pitfalls)

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes

Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Literature

Book

Sethi, A. “From Science to Startup”
ISBN 978-3-319-30422-9
This course will enhance students' understanding of the complexity of hierarchical relationships in the workplace in weekly lessons that include lectures, analyses of leadership situations (e.g., case studies), exercises, and group discussions. More specifically, students will be taught about different leadership styles and how power and leadership play out in social interactions. Emphasis is placed on leadership skills training report (~30 hours) and the development and the implementation and application of topics to the workplace context.

### Content

- Introduction to the course and the topic of power and leadership, definitions
- Leadership styles and theories: Universalist theories, behavioral theories, contingency theories, "new leadership" theories
- Leadership, communication, and interpersonal skills (3 sessions): 1. Effective communication: Listening and speaking, running effective meetings, delegating effectively, giving performance feedback, 2. Hierarchy and communications: Pitfalls and solutions, communication training, 3. Importance of social skills for leadership effectiveness
- Agility in teams: Overview of the Scrum Framework in the context of software development, leadership in agile teams, the role of motivation, training: experiencing first-hand how to develop a product in an agile way
- Power abuses, ethics in leadership: Why do leaders behave unethically? Destructive leadership: theories, examples, and consequences
- Diversity and discrimination in relation to power and leadership: Expectations, bias, and discrimination the workplace, sources of bias, how to reduce bias and discrimination
- Leadership and innovation: Which are the particular paradoxes and trade-offs leaders face when they are leading for innovation? How could they successfully manage these challenges?

### Homework

- Analysis of Visionary Speeches (~10 hours)
- Preparation of a video of a 2-min speech (incl. training, ~12 hours)
- Providing feedback to two of your classmates on their leadership skills (~6 hours)
- Writing a leadership skills training report (~30 hours)
- Mandatory and facultative readings and exercises (~10 hours)

### Literature

### Taught Competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Communication: assessed
- Cooperation and Teamwork: assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed

**Domain C - Social Competencies**
- Domain C - Social Competencies: assessed
  - Cooperation and Teamwork: assessed
  - Leadership and Responsibility: assessed
  - Self-presentation and Social Influence: assessed
  - Sensitivity to Diversity: assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### 363-0311-00L Psychological Aspects of Risk Management and Technology

**Number of participants limited to 65.**

**Abstract**
Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are treated. Three components of risk management (risk identification/evaluation, risk mitigation, risk communication) and underlying psychological and organizational processes are discussed, using company case studies to promote in-depth understanding.

**Objective**
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of "Psychological Aspects of Risk Management and Technology" together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

**Content**
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations.

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication
- Psychological and organizational concepts relevant in risk management:
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty
- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

**Lecture Notes**
There is no script, but slides will be made available before the lectures.

**Literature**
There are texts for each of the course topics made available before the lectures.

**Prerequisites / Notice**
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

### 363-1050-00L Simulation of Negotiations

**Limited number of participants.**

**Abstract**
The Global Studies Institute (University of Geneva) is organizing a simulation seminar on Nagorno-Karabakh in collaboration with MGIMO Moscow (TBC) and the Chair of Negotiation and Conflict Management (ETHZ).

**Objective**
Students will have the possibility to participate in simulated diplomatic negotiations and to analyse and assess the negotiation logic behind the situation. During the course, they should gain insight into the negotiations between Armenia, Azerbaijan, and the international community, as well as negotiation techniques in general.

**Prerequisites / Notice**
Students who wish to register for this course have to apply no later than 18 September. Please send your application to Andreas Knobel: aknobel@ethz.ch, additionally register in mystudies (technical note for the registration: All registered students will initially be placed on a waiting list).
In the lectures, students will be provided with basic information related to Nagorno-Karabakh. The historical, military, economic and political dimensions, including the various treaties and existing agreements and their evolution will be analyzed. Students will as well participate in an introduction on negotiation techniques, particularly on the negotiation engineering approach. On the basis of the comprehensive analysis, negotiation scenarios will be developed and subsequently tested during a two-day simulation exercise. The simulation exercise will be prepared with the help of experienced negotiators and experts.

The simulation exercise is intended for Masters degree and PhD students. The course will be taught in English. The project is headed by Prof. Micheline Calmy-Rey and Prof. Nicolas Levrat, Global Studies Institute, University of Geneva.

Students who wish to register for this course have to apply no later than 18 September 2021. Please send your (brief) application with your background and motivation to Andreas Knobel: aknobel@ethz.ch, additionally register in mystudies (Technical note for the registration: All registered students will initially be placed on a waiting list.)

The homepage for this course with more information is located at: https://necom.ethz.ch/education/simulation-of-negotiations.html.

Students from ETH Zurich and MGIMO will participate in the seminar sessions via video conferencing. They will go to Geneva for the simulation exercise on 2 and 3 December 2021.

There will be two exercise sessions (see separate course 363-1050-01L).

Content

- Understand relevance of work design for company performance and strategy
- Understand the interaction between organization and technology and its impact on organizational change
- Understand links between design of individual jobs and work processes

Setting.

Sustainable organizational change. As course project, students learn and apply a method for analyzing and designing work in business settings.

Simulation of Negotiations (Exercises)

Technological ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

The two main aims of the exercises are: 1) to become familiar with the historical, economic, political dimensions of the conflict in Nagorno-Karabakh (first session); 2) to work on the mandates for the simulation under supervision of the lecturers (second session).

For the first session students will be asked to prepare and deliver a 15 minute talk on some aspect of the conflict.

1. Attend all seminar sessions either in person or via video conference and actively participate in discussions.
2. Participant in person in the two-day simulation exercise (19-20 November 2020).

Il. Texts to be submitted before, during and after the simulation (50%)

1. Before the simulation: Prepare a 4-5 page summary of your group's negotiating mandate, including a description of the positions of all the parties (group evaluation).
2. During the simulation: Draft and present an introductory and final statement (group evaluation).
3. After the simulation: Prepare a report on the negotiation outcomes to the organization, state or region you represent (3-4 pages) and a press release (max. 1 page). The report and press release are individually evaluated.

Prerequisites / notice

I. Active participation in class (50%)

2 credits

M. Ambühl, A. Knobel

The Global Studies Institute (University of Geneva) is organizing a simulation seminar on the conflict in Nagorno-Karabakh in collaboration with MGIMO Moscow (TBC) and the Chair of Negotiation and Conflict Management (ETHZ).

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The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks by guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:
- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change methods
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

The course consists of two parts. Part I provides an introduction into important topics in the field of the economics of innovation. Part II consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about the digitization of firms, data about environmentally friendly innovations, or patent data. In part I we will learn about a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. ... b) the role of competition and market structure for the R&D activities of companies. ... c) how digital and environmentally friendly technologies diffuse among firms. ... d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. ... e) how we can measure the returns to R&D activities. ... f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.

The course includes the completion of a course project to be conducted in groups of four students. The project entails applying a particular method for analyzing and designing work processes and is carried out by means of interviews and observations in companies chosen by the students.

#### Natural Resources

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-1036-00L</td>
<td>Empirical Innovation Economics</td>
<td>W</td>
<td>3</td>
<td>1G</td>
<td>M. Wörter</td>
</tr>
</tbody>
</table>

**Abstract**
The course focuses on important factors that drive the innovation performance of firms, like innovation capabilities, the use of digital technologies, environmental and innovation policy and it shows how innovation activities relate to firm performance and to the technological dynamic of industries. We also discuss the implications of the findings for effective economic policy-making.

**Objective**
The course provides students with the basic skills to understand and assess empirically the technological activities of firms and the technological dynamics of industries. In addition, the aim is to promote the understanding of the essential criteria for innovation policy-making.

Personal and social skills are also addressed during the course. In particular, there is the possibility to improve communication and presentation skills, the ability to develop arguments for the positions of political representatives, policy-makers, pressure groups, or NGOs in connection with innovation policy-making.

**Content**
The course consists of two parts. Part I provides an introduction into important topics in the field of the economics of innovation. Part II consists of empirical exercises based on various firm-level data sets, e.g., the KOF Innovation data, data about the digitization of firms, data about environmentally friendly innovations, or patent data. In part I we will learn about a) market conditions that encourage firms to invest in R&D (Research and Development) and develop new products and processes. ... b) the role of competition and market structure for the R&D activities of companies. ... c) how digital and environmentally friendly technologies diffuse among firms. ... d) how the R&D activities of firms are affected by economic crises and how firms finance their R&D activities. ... e) how we can measure the returns to R&D activities. ... f) how environmental policies and innovation policies affect the technological activities of a firm. In part II we will use the KOF Innovation Survey data, patent data, data on digitization of firms, or other longitudinal data sources, to investigate empirically the technological activities of firms in relation to the topics introduced in part I.

**Lecture notes**
Will be provided in the course and in the e-learning environment: https://moodle-app2.let.ethz.ch/course/view.php?id=15120

**Literature**
Literature will be presented in the course. For an introduction into the economics of innovation see G.M. Peter Swann, The Economics of Innovation - an Introduction, Edward Elgar, 2009.


**Prerequisites / notice**
Course is directed to advanced Master-Students and PhD Students with an interest in empirical work.

## The Economics of Climate Change

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-1106-00L</td>
<td>The Economics of Climate Change</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Goussebaile</td>
</tr>
</tbody>
</table>

**Abstract**
After an introduction to the issue of climate change, we will see the policy instruments that can be used to mitigate it. We will then discuss the optimal level of these policies. Finally, we will analyze the political constraints that limit their implementation.

**Objective**
Students will acquire a general understanding of the problem faced by the society with climate change, as well as the ways and the obstacles to deal with it. From a technical point of view, this course intends to teach participants the main tools used in economic sciences to discuss the problem of climate change, understand its key determinants, advise policy makers and understand the constraints of the latter.
### Finance and Investment

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-1081-00L</td>
<td>Asset Liability Management and Treasury Risks</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>P. Mangold, M. Eichhorn</td>
</tr>
<tr>
<td>363-0723-00L</td>
<td>Corporate Finance</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Kind</td>
</tr>
</tbody>
</table>

#### Abstract

**Asset Liability Management (ALM)** is key to the financial success of any corporation. The goal is to develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and related profits and losses, including identification and mitigation of undue risks taken. This course is geared towards preparing students to apply these concepts in practical settings.

**Objective**

The main learning objectives of this course are:
- develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and their respective contribution to profits and losses
- measure and assess exposures to risk factors such as interest and FX rates, equity and commodity prices, as well as liquidity events
- trading and hedging to mitigate undue risks incurred

**Content**

The course is organized around a series of case studies. We will first discuss and develop an understanding of the fundamentals on different aspects of the management and risk management of the balance sheet. Using real life case studies each concept will then be directly applied and tested. In-class discussions, presentations and one written assignment are used to facilitate active and interactive learning in a stimulating environment. During the case studies students will frequently work in small groups. Therefore, the number of participants is limited to 40.

The course focuses on the application of finance concepts to the financial management of corporations and is geared towards preparing students to apply these concepts in practical settings. Executives of all sectors are expected to have a sound understanding of the content covered. As such, the course is not exclusively targeted at students who are considering a career in the financial services sector. It also recommended for students who want to work in the finance, treasury or risk area of corporates. It is also suitable for students who want to work for a consultancy firm.

**Literature**

No single textbook covers the course, below we list some useful references. Further materials will be made available to students prior to the lectures


**Prerequisites / notice**

Participants should have a basic understanding of financial management, gained, for example, from prior undergraduate economics, business, or accounting studies.

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The introductory part will explain why climate change represents a main issue for our societies. We will see the anthropogenic causes (i.e. greenhouse gas (GHG) emissions), the physical mechanism and the economic consequences of climate change. Then, we will introduce economic science modeling with the notion of externality to explain the excessive GHG emissions and characterize the societal challenge raised by climate change.

The second part of the course will present the different policy instruments for reducing GHG emissions (emission taxes, abatement subsidies, cap-and-trade system, standards). We will compare their performance and their distributional effects with regard to several aspects, with a special focus on the impact of uncertainty.

The third part of the course will focus on the level at which climate policies should be implemented, which depends on the cost of emission abatement and the benefit of climate change mitigation. We will detail the economic models developed to evaluate the optimal GHG emission abatement, namely Integrated Assessment Models. We will then analyze the main drivers of the optimal abatement level, in particular discounting and technological changes.

The last part of the course will address the reasons why policy makers have only weakly implemented climate change policies up to now. We will discuss the difficulties of finding an international agreement for GHG emission reduction in a world with a large number of countries. We will also see why the time delay between GHG emissions and climate change may make society and policy makers reluctant to implement significant climate change policies.

Lecture notes

Lecture Notes of the course will be sent by email to officially subscribed students.

Literature

The main reference of the course is the set of lecture notes; students will also be encouraged to read some influential academic articles dealing with the issues under study.

Prerequisites / notice

Elementary knowledge of economic theory is a plus but not a prerequisite.

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"Corporate Finance" is an introductory course that presents those fundamental principles of finance that find direct application in the financial decisions of modern corporations. The course is structured in three parts: (i) Corporate Finance and Corporate Governance, (ii) Investment Decisions/Valuation, (iii) Financial Policy.

In the following, for each of the three parts of the course, key aspects, are listed.

Part I: Corporate Finance and Corporate Governance
- Corporations and their characteristics (e.g., centralized management, limited liability, free transferability of economic claims, legal personality)
- Corporate finance and its goals (e.g., shareholder-value approach vs. stakeholder-value approach)
- Corporate governance problems and possible solutions (e.g., over-investment, under-investment, self-dealing, monetary incentives, board of directors, the market of corporate control, leverage, product-market competition)

Part II: Investment Decisions/Valuation
- Discounting and compounding
- Present value tools (e.g., perpetuities, growing perpetuities, annuities, growing annuities)
- Bond pricing and interest rates (e.g., types of bonds, term structure of interest rates, yield-to-maturity, duration concepts, forward rates, "riding the yield curve")
- Risk and return (e.g., moments of stock returns, modern portfolio theory, capital market line, systematic risk vs. unsystematic risk)
- CAPM in practice (e.g., computation of the risk free interest rate, beta, and the market risk premium; security market line)
- DCF Analysis: Cost of capital and cash flow estimation
- Relative valuation (e.g., earnings multiples, book multiples, sales multiples, fundamental drivers of multiples)
- Real options (e.g., option to abandon, option to delay, option to expand)

Part III: Financial Policy
- Corporate financing (e.g., instruments, internal vs. external financing, equity financiang vs. debt financing, crowdfunding, M&M and beyond)
- Payout policy (e.g., dividends, par value reductions, share buybacks, M&M and beyond)

Lecture notes
Slides in English (and any other relevant material) will be available for download on the following website: https://moodle-app2.let.ethz.ch/course/view.php?id=4479

Literature
For the exam, only the material provided will be relevant. However, interested students may refer to the following textbook for an alternative, or a complementary, reading:

Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0881-00L</td>
<td>Semester Project Small ♠</td>
<td>W</td>
<td>3 credits</td>
<td>6A</td>
<td>Professors</td>
</tr>
<tr>
<td>Abstract</td>
<td>The semester project (90 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.</td>
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<td>Objective</td>
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</table>

| 363-0883-00L | Semester Project Large ♠ | W    | 6 credits | 13A | Professors |
| Abstract | The semester project (180 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution. |
| Objective | The semester project (180 hours) is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution. |

| 363-1042-00L | Strategic Career Development | Z    | 0 credits | 1V  | P. Cettier |
| Abstract | The offer Strategic Career Development has the goal to support students in the development and alignment of their personal & professional goals. Orientation, Goal setting, action plan development, motivation letter, CV, interview training We will include high level external guest speakers |
| Objective | We will discuss and develop answers to the following questions: What do I want to achieve in my life? Why is it important to define goals? What decision criteria can I use as a guide? How do potential career paths look like? What are the possibilities? How does the life cycle of a career look like? What are the alternatives? How do I increase my chances of success/reaching my goals? How did others do it? What kind of advice can experienced captains of industry give? Why is a periodic check of my goals and my progress necessary? |
INTRODUCTION
Awareness building / Overview on the career life cycle / Examples from praxis / Exchange of experiences / Approach for goal setting / Introduction to the success secrets of a career

ORIENTATION AND GOAL SETTING
Class discussion of the success secrets of a career / Orientation on career options / Discussion of possible decision criteria / Initial formulation of concrete goals

External guest speaker: Inspiring Start-up Entrepreneur

CAREER DEVELOPMENT PLANS
Exchange w/ representatives of industries / Personal Values & Norms vs Corporate Identity / Work-Life Balance Gender / Diversity / Summary of discussions / Best practice / Modification/Sharpening of goals

External guest speaker: Representatives from Hilti AG Switzerland

DETAILING OF INDIVIDUAL CAREER PLANS
Development of detailed individual career plans / Next steps / action plan / Tips & Tricks for careers in organizations and entrepreneurship

REVIEW & APPLICATION COUNSELING
Review/check of goals and career plans / Motivation letter / CV / Preparation for interviews

INTERVIEW TRAINING

Lecture notes
In today’s world of everything is possible it becomes an every increasing challenge to find orientation, to define a goal for which it is worth to work for with focus and energy. But this is exactly what is so important in today’s work environment. Only with a definite goal one can decide if the taken path is right, one can develop enough motivation to go beyond the comfort zone. With a definite goal, one increases the chances of success of one’s education and career. The earlier one has defined what he/she wants to achieve, the bigger the effect.

Prerequisites / notice
Motivation. Strategic long-term view.

Supplementary Courses
The students have to deepen their knowledge in the area(s) of engineering/natural sciences in consultation with the responsible professor (tutor). Core courses and electives of D-MTEC can not be used as supplementary courses.

Course Catalogue of ETH Zurich

Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0879-00L</td>
<td>Practical Training</td>
<td>O</td>
<td>6</td>
<td></td>
<td>external organisers</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>The practical experience gained by the student complets the studies at the Swiss Federal Institute of Technology and prepares her/him for future activities in industry.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>The practical experience gained by the student complets the studies at the Swiss Federal Institute of Technology and prepares her/him for future activities in industry.</td>
</tr>
</tbody>
</table>

Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0600-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30</td>
<td>57D</td>
<td>Professors</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and normally deals with a subject contained in the major fields. The research will be performed normally within a private company or at the ETH Zurich.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and normally deals with a subject contained in the major fields. The research will be performed normally within a private company or at the ETH Zurich.</td>
</tr>
</tbody>
</table>

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-1063-00L</td>
<td>Academic Writing Course</td>
<td>O</td>
<td>0</td>
<td>1G</td>
<td>R. Mihalka</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>This course for MTEC master's students will focus on developing and refining students' English writing skills and their understanding of the requirements and conventions of academic writing.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>The course develops a range of practical and transferrable writing skills. Its first aim is to improve the academic writing skills necessary for the successful completion of an MSc thesis. The course provides theoretical input, practical writing exercises, and detailed individual feedback. It is organized into an initial group lecture and four subsequent workshops in smaller tutorial groups. The group lecture raises awareness about academic conduct, especially with regard to plagiarism. Afterwards, students take placement tests so that the areas where they need improvement can be identified. The following workshops concentrate on these highlighted areas, and feedback on placement tests is integrated into the input and practice during these sessions. Students can use the skills developed on the course to improve the overall quality of their MSc theses and to produce their thesis more rapidly and efficiently. These skills can also be used beyond the MSc, whether students go on to complete a PhD or to produce reports and other documents in industry.</td>
</tr>
</tbody>
</table>
Content

Group lecture:
an introduction to writing an MSc thesis in D-MTEC
selecting topic and supervisor
academic expectations
avoiding plagiarism

Workshop 1:
the writing process
reading, note taking and planning
overview of the thesis structure
building academic vocabulary

Workshop 2:
writing methods sections
embedding figures and tables
structuring sentences and paragraphs
noun phrases and articles

Workshop 3:
introductions; results and discussion sections
writing critically
relative clauses

Workshop 4:
abstracts and conclusions
editing your own text
punctuation, spelling, and grammar

Lecture notes
Notes will be available after registration.

Management, Technology and Economics Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The following programming concepts are introduced during this module:

1. Variables, data types
2. Condition check, Loops, logics
3. Arrays
4. Functions
5. Matrices
6. Data management (SQL)

In the practical part of the course, students work on small programming projects with a context from natural sciences. Electronic tutorials are available as preparation.

Objective

- how to encode a problem into a program, test the program, and correct errors.
- to understand and improve existing code.
- to implement mathematical models as a simulation.

Prerequisites / notice

No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.

In this module, basic paradigms and techniques in working with data will be discussed, especially towards data security, managing data decentrally, and learning from data.

Participants learn about some important computer science concepts necessary for data science. They understand some of these concepts in detail and see the mathematics behind them.

Participants will get an introduction to key computer science concepts underlying current and upcoming technology. The module in particular covers cryptography and digital signatures, networking and distributed algorithms, distributed ledger technology, as well as machine learning (supervised and unsupervised learning). Each topic will be discussed in two different ways: (i) a hands-on and in-depth introduction that allows participants to gain a technical understanding of key ideas. This is supported by simple and concrete examples as well as programming assignments; (ii) a context part that addresses the challenges and limitations encountered in practical applications.

Participants understand basic concepts of visual recognition systems of the last two decades, mostly focusing on technologies and respective business changes, and it will specifically address the communication between technical experts and business management. The studied cases are currently planned to focus on artificial intelligence, IoT including edge and cloud computing, blockchain and distributed ledger technologies, and cybersecurity and data protection regulations (subject to change).

Participants will explore how new information technologies change different aspects of a business, and learn how to evaluate specific risks, costs, and benefits of such technologies. The module will shed light on success factors and common pitfalls when implementing new technologies and respective business changes, and it will specifically address the communication between technical experts and business management. The studied cases are currently planned to focus on artificial intelligence, IoT including edge and cloud computing, blockchain and distributed ledger technologies, and cybersecurity and data protection regulations (subject to change).

This module offers practical knowledge in visual information processing and human computer interactions.

Participants understand basic concepts of visual recognition and human-computer interaction systems.

The first part of the module will cover basic theoretical knowledge on visual recognition systems of the last two decades, mostly focusing on the most recent advancements in deep learning and convolutional neural networks. The theoretical knowledge will be supported with practical sessions that will allow participants to gain hands-on experience with most commonly used tools and deepen their understanding of the key concepts. The second part provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

This integration module for CAS "Applied Information Technology" links technical understanding of technology with business strategy based on a set of case studies from practice.

Participants will learn how technology affects businesses and practical issues when using new technologies in incumbent organizations based on a set of case studies.

Participants will explore how new information technologies change different aspects of a business, and learn how to evaluate specific risks, based on a set of case studies.

No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.

This course provides an introduction to research & development, both as a general activity and as a dedicated function within a corporation. Participants will learn how to organize, conduct and manage individual R&D projects as well as groups of projects. We will also look at the various roles that R&D serves within a corporation and how choices regarding the organization of R&D align with these roles.

The aim of this course is to develop the participants’ ability to articulate a coherent plan for R&D activities linked to the business needs of a corporation, including the ability to explain convincingly the rationale, structure, resources and intended outcomes of the R&D.

No prior knowledge is required for this course. It is based on application-oriented learning. The students spend most of their time working through programming projects and discussing their results with teaching assistants. To learn the programming basics there are electronic tutorials available.

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### 247-0201-00L Innovation Opportunity Analysis

**Abstract**
The Innovation Opportunity Analysis course is designed as a practical introduction to evaluating technology-based innovation opportunities in a corporate setting. The course will cover several fundamental innovation frameworks and principles before diving deeper into individualized content using the principle of Guided Learning.

**Objective**
The primary goal of the course is to develop the skills needed for identifying technology-based innovation opportunities and for planning successful innovation projects. An additional goal is to prepare participants for their Master's thesis and for life-long learning in technology-based innovation.

### 247-0202-00L Innovation and Technology Tools

**Abstract**
This module will provide an introduction to some of the fundamental tools that can be used for evaluating technologies and innovation opportunities.

**Objective**
The goal is to enable participants to use basic innovation and technology evaluation tools within their work setting.

### 247-0203-00L Experiment Selection & Design

**Abstract**
This module prepares participants to conduct an experimental project in an ETH lab beginning in the following January as part of the MAS in Applied Technology programme. Participants will prepare a plan and design for the experimental project under the direction of the CAS Programme Director and the relevant ETH lab.

**Objective**
The goal is for participants to learn standard procedures for the planning and design of experiments and to gain practical experience in planning and designing an individual experimental project.

#### Experimental Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>247-0550-00L</td>
<td>Project</td>
<td>O</td>
<td>10 credits</td>
<td>18A</td>
<td>U. Grossner</td>
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</table>

#### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>247-0500-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Professors</td>
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### MAS in Applied Technology - Key for Type

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
<th>Code</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
</tr>
<tr>
<td>E-</td>
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<td>Z</td>
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<td>Dr</td>
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<td></td>
</tr>
</tbody>
</table>

### Key for Hours

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<tbody>
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<td>revision course / private study</td>
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</tbody>
</table>

**ECTS**
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
MAS in Architecture and Digital Fabrication

The MAS Digital Fabrication is a 1-year full-time programme and is structured as a series of teaching modules with an independent master thesis. Lessons within the modules are given in the form of lectures, practical workshops, and projects as the main modus for developing skills. Learning will be supported through one on one mentoring in studio, group critiques, symposia, and excursions.

### Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>069-0001-00L</td>
<td>Digital Foundations</td>
<td>O</td>
<td>20 credits</td>
<td>2G</td>
<td>B. Dillenburger, P. Aejmelaeus-Lindström</td>
</tr>
</tbody>
</table>

**Abstract**

Digital Foundations introduces students to information technology in architecture, to computational design and how robotic fabrication processes as well as 3D printing technologies are used to translate computational design models into physical objects and building components.

**Objective**

Students learn basic programming paradigms such as control structures and object-oriented programming, the foundations of computational geometry and explore generative form-finding. Using Python as a main programming language within the frameworks of Processing, Rhino and Grasshopper, students learn to translate design thinking into computational algorithms. Furthermore, students learn about data preparation and toolpath creation for 3D printing (predominantly binder jet-printing and fused-deposition-modelling), and familiarise themselves with various mechatronic setups, materials and control-strategies of additive manufacturing.

Students are taught the basic principles of working with industrial robotic arms in the field of architecture. Students practice different concepts of robotic control, which enables them to execute basic routines. They are able to write their own programmes and directly control the robotic set-up using UR-Script and custom Python modules. Through multiple exercises, students learn how to design and robotically build small-scale spatial structures exhibiting the potential of robotic fabrication processes. Additionally, they employ simple feedback loops for improving the accuracy of the fabrication process and as design-drivers.

---

**MAS in Architecture and Digital Fabrication - Key for Type**

- **O** Compulsory
- **W+** Eligible for credits and recommended
- **W** Eligible for credits
- **E-** Recommended, not eligible for credits
- **Z** Courses outside the curriculum
- **Dr** Suitable for doctorate

**Key for Hours**

- **V** lecture
- **G** lecture with exercise
- **U** exercise
- **S** seminar
- **K** colloquium
- **P** practical/laboratory course
- **A** independent project
- **D** diploma thesis
- **R** revision course / private study

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>072-0001-00L</td>
<td>Construction Industry and Real Estate Market</td>
<td>O</td>
<td>3 credits</td>
<td>7G</td>
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</tr>
<tr>
<td></td>
<td><em>Does not take place this semester.</em></td>
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<tr>
<td></td>
<td>Only for MAS in Architecture, Real Estate, Construction.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>In the first term of MAS ETH ARC, the students knowledge of the construction sector and the real estate market will be reinforced and deepened, along for an informed interpretation of the stakeholders’ decision making processes. It explores the topics of involved parties and perception of demand. Additionally, it will guide students in developing their research proposals and research questions.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The first term of MAS ETH ARC supports the students’ expertise and personal skills and develops their reasoning and creative thinking skills. It compels the students to understand both ambitious projects and complex properties, to pursue long-term intentions, to carry out specific tasks, and to become aware of the consequences of their decisions. Over the course unit, students review and closely examine the expertise which they have gained so far. The course directs students to draw independent conclusions and to set forecasts as professionals. Ultimately, the knowledge and expertise which is gained throughout the unit will allow the students to fully realise their role as a professional in their field.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>In the first term of MAS ETH ARC, the students knowledge of the construction sector and the real estate market will be reinforced and deepened, along for an informed interpretation of the stakeholders’ decision making processes and interests. It also explores the topics of involved parties and perception of demand. Additionally, it will guide students in developing their research proposals and research questions.</td>
<td></td>
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</tr>
<tr>
<td>Key words of the course unit</td>
<td>Project and property, design and building process, involved parties and services, interests, basic knowledge and terms, perception and dissociation, sustainable decisions, and life cycle</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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</table>

### Major in Digitalisation

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>072-0003-00L</td>
<td>Methodology</td>
<td>O</td>
<td>1 credit</td>
<td>2G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only for MAS in Architecture, Real Estate, Construction.</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>In the fourth term of MAS ETH ARC, the students will guide through the process of methodology which is the ability to put their attitude into practice. Additionally, the course unit puts emphasis on the research findings and finalisation of the written work.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The fourth term of MAS ETH ARC supports the students’ attitude and practice and methodology. It compels the students to analyse issues and carry out solutions. Ultimately, the knowledge and expertise which is gained throughout the unit will allow the students to fully realise their role as a professional in their field.</td>
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</tr>
<tr>
<td>Content</td>
<td>In the fourth term of MAS ETH ARC, the students will guide through the process of methodology which is the ability to put their attitude into practice. Additionally, the course unit puts emphasis on the research findings and finalisation of the written work.</td>
<td></td>
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</tr>
<tr>
<td>Key words of the course unit</td>
<td>Objectives, methodology, research, analysis and interpretation, academic writing, text understanding, publishing</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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</tbody>
</table>

### Does not take place this semester.

#### Module 1: Foundations of Digitalisation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>072-0101-00L</td>
<td>Module 1: Foundations of Digitalisation</td>
<td>W</td>
<td>1 credit</td>
<td>2G</td>
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<tr>
<td></td>
<td>Only for CAS ARC in Digital and MAS in Architecture, Real Estate, Construction.</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Key terms: Digital transformation is more than digitisation of existing processes and information</td>
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<tr>
<td>Objective</td>
<td>Independently of the building industry, Module 1 initially provides information about the characteristics of digitalisation through its principles and rules, enabling the participants to independently recognise the short-term and long-term changes that are resulting from it.</td>
<td></td>
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<tr>
<td>Content</td>
<td>The first module addresses the topic of digitalisation and digital transformation in a holistic sense. It is much more than converting documents into PDFs or using software. It is about transforming processes, resources and information into a consistent and efficient digital system to make life easier for employees and customers. This journey always involves change. From the perspective of other industries, we first build up a basic understanding and discuss the opportunities and risks.</td>
<td></td>
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</tr>
<tr>
<td>How do the experiences of other industries help us? What can be derived from them? Why is BIM only a small part and why is the future of BIM not BIM?</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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#### Module 2: Collaboration

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>072-0102-00L</td>
<td>Module 2: Collaboration</td>
<td>W</td>
<td>1 credit</td>
<td>2G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only for CAS ARC in Digital and MAS in Architecture, Real Estate, Construction.</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Key terms: &quot;Behaviour for Collaboration&quot; - Structural questions on collaboration and the patterns of behaviour.</td>
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</tr>
<tr>
<td>Objective</td>
<td>In Module 2, we break from the theoretical idea of a purely technology-based, better collaboration and look at the situation realistically in order to be able to understand and develop new solutions and requirements.</td>
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</tr>
<tr>
<td>Content</td>
<td>The usual approach towards digital transformation is to train people to use new technologies. In contrary, we ask for the specific challenges and problems people have with change. We learn to understand viewpoints of different partners within building projects and new solutions to specific problems.</td>
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<tr>
<td>Lecture notes</td>
<td>Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.</td>
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<tr>
<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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</tbody>
</table>
Module 3: Foundation of Automation

Only for CAS ARC in Digital and MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Managed data, semantics and file formats

Objective
Module 3 we leave behind the negative images from the early days of automation. A gloomy and misanthropic image of automation - both a bliss and a curse. We get to know the positive sides and learn to apply them. How do we become a sustainable "Formula 1"?

Content
What does it take to be able to work together in a digitally networked environment? How many "techie genes" are needed to work efficiently and effectively with structured data? The third module gives an insight into the principles of data architectures, data formats, attributes and platform technology. Machine readability as an important requirement but also as a clear challenge e.g. to security requirements.

Lecture notes
The module offers the opportunity to prepare for the voluntary buildingSMART Professional Certification.

Literature
Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.

Module 4: Foundation of Value Creation

Only for CAS ARC in Digital and MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Added value of digital transformation, distributed data management, digital twin, logistics and robotics.

Objective
Using specific examples, Module 4 illustrates the foundations and versatility of building information modeling (BIM), enabling participants to deal with the concepts, applications and mechanisms involved.

Content
"Highway to hell or highway to heaven" - the question of a clear and simple roadmap is always at the heart of a digital transformation. "Value creation" is a central goal. Digitalisation is often seen as a strategy from the productivity gap. The fourth module shows how strategic goals can be developed in a roadmap and implemented in practice and how the individual shareholders and stakeholders participate.

Lecture notes
We learn to consciously look at the topic of added value and digital transformation from different perspectives. Collision checking and quantity take-offs (QTO) are very useful. But they are only basics when it comes to real value creation.

Literature
Scripts, documents, studies, dates and addresses are stored on the server of the program and accessible to students on the Miro Board.

Module 5: New Business Modelle

Only for CAS ARC in Digital and MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Business models, cultural change, disruption, evolution, lean methods

Objective
Module 5 focuses on cultural change, innovation, disruption or evolution? In this last model, we learn to question and discover what the 17 Sustainable Goals mean for our industry.

Content
As a final module, new business models are discussed and explored. Examples will be used to explore patterns and interfaces and to analyse what is needed today and in the future for a successful and sustainable development of the sector. How can innovative ideas move us forward? What can we learn from design thinking? Why is it important for people to have useful and understandable measurable values? How do the 17 Sustainable Goals influence our industry?

Lecture notes
We will analyse the topic on the basis of two concrete examples, familiarise ourselves with them and observe their further development as a result.

Literature
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Term Paper
The Term Paper is offered in spring semesters only.

Major inProject

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>072-0103-00L</td>
<td>Module 3: Foundation of Automation</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
</tr>
<tr>
<td>072-0104-00L</td>
<td>Module 4: Foundation of Value Creation</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
</tr>
<tr>
<td>072-0105-00L</td>
<td>Module 5: New Business Modelle</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
</tr>
</tbody>
</table>

Autumn Semester 2021

The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.

- Phases and services
- Due diligence and duty of loyalty
- Duties and tasks, liability
- Working packages
- Management and coordination

Content

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Lecture notes

Please find the teaching material, the further readings and Information on our server.

Literature

www.map.arch.ethz.ch/en

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Module 1: Perception of Demand

Lecturers

In Module 1, by interpreting the snapshot of one's own enterprise and opportunities and dangers

1 credit

www.map.arch.ethz.ch/en

---

Module 2: State of the Art

A. Paulus

www.map.arch.ethz.ch/en

---

Module 4: Guiding/Steering/Leading

072-0204-00L Module 4: Guiding/Steering/Leading

Only for CAS ARC in Project and MAS in Architecture, Real Estate, Construction.

W 1 credit 2G A. Paulus

Abstract

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Objective

The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.

- Management and administration
- Leadership
- Team performance
- Motivation and conflict resolution

Content

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Lecture notes

Please find the teaching material, the further readings and Information on our server.

Literature

www.map.arch.ethz.ch/en

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Module 5: Project

072-0205-00L Module 5: Project

Only for CAS ARC in Project and MAS in Architecture, Real Estate, Construction.

W 1 credit 2G A. Paulus

Abstract

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Objective

The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.

- Decision making
- Future perspectives
- Micro and macro environment
- Strength and flexibility

Content

Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Lecture notes

Please find the teaching material, the further readings and Information on our server.

Literature

www.map.arch.ethz.ch/en

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Term Paper

The Term Paper is offered in spring semesters only.

Major in Real Estate Strategies urban-peri-urban

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>
| 072-0301-00L | Module 1: Perception of Demand                  | W    | 1    | 2G    | Real Estate, Construction.
|          | Does not take place this semester.               |      |      |       | Only for CAS ARC in Real Estate Strategies urban-peri-urban and MAS in Architecture. |
|          | Key words: construction and real estate market, micro and macro environment |      |      |       | |
|          | By interpreting the snapshot of one's own enterprise and opportunities and dangers to appreciate. |      |      |       | |
| 072-0302-00L | Module 2: State of the Art                      | W    | 1    | 2G    | Real Estate, Construction.
|          | Does not take place this semester.               |      |      |       | Only for CAS ARC in Real Estate Strategies urban-peri-urban and MAS in Architecture. |
|          | Key words: Bauwerk Schweiz, new construction and renovation, economy |      |      |       | |
|          | Change in value, demolition / replacement, potential for compression |      |      |       | |
|          | Knowledge about type, extent and change of the building Switzerland and the main questions. |      |      |       | |
| 072-0303-00L | Module 3: Economic Interest                    | W    | 1    | 2G    | Real Estate, Construction.
|          | Does not take place this semester.               |      |      |       | Only for CAS ARC in Real Estate Strategies urban-peri-urban and MAS in Architecture. |
|          | Key words: intention development, realization operation |      |      |       | |
|          | The participants understand a property in the context of a life cycle |      |      |       | |

The importance of a life-cycle-oriented approach has arrived in the Swiss construction and real estate sector. Cumulative management costs can exceed the cost of construction after just a few years. In this module, a systematic consideration of the phases and processes in the life cycle of a property takes place. Study I explores various aspects of life-cycle planning and construction.

Module 4: Course of Action
Does not take place this semester.
Only for CAS ARC in Real Estate Strategies urban peri-urban and MAS in Architecture, Real Estate, Construction.

Abstract
Key words: maintenance, change, replacement
Preservation of value, increase in value, destruction of value and replacement construction

Objective
The various depths of intervention in dealing with a existing property and their effects are known.

Content
The structure and nomenclature of the interventions in the stock are presented and models for the registration and calculation of the structural interventions are presented. It focuses specifically on ongoing maintenance, the periodic repair and planning of renewal cycles, as well as on structural interventions and value-enhancing measures. Based on the study II, the learning content is applied and various options for action in dealing with the building stock are evaluated.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Module 5: Life Cycle and Resources
Does not take place this semester.
Only for CAS ARC in Real Estate Strategies urban peri-urban and MAS in Architecture, Real Estate, Construction.

Abstract
Key words: building fabric, material cycle
Reusability of building fabric, energy flows, pollutants

Objective
Building and breaking off is understood as an energy and material flow.

Content
The total weight of all properties in Switzerland is estimated at around 1 billion tonnes. Every year around 10 million m³ of buildings are demolished and more than 60 million t of raw materials are used in new buildings. This module examines the cycle principle and its implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of materials.

Lecture notes
Continuation, reuse, demolition / new construction - stakeholders, goals and conflicting goals

Literature
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

**Term Paper**
The Term Paper is offered in spring semesters only.

**Major in Company Management**

**Core Courses**

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>072-0401-00L</td>
<td>Module 1: Market</td>
<td>W</td>
<td>1</td>
<td>2G</td>
<td>A. Paulus</td>
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<tr>
<td></td>
<td>Only for CAS ARC in Unternehmensführung und MAS in Architecture, Real Estate, Construction.</td>
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<tr>
<td></td>
<td>Key terms: Market, purpose and business model</td>
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<td></td>
<td>The aim is to use a snapshot in time to interpret one’s own company and become able to assess opportunities and risks.</td>
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<td></td>
<td>The “company” module considers the roles of organisations within the economic network of the markets and the nature of their identity. It presents the essential aspects of planning offices as service providers, illustrates various types of company, and discusses companies’ lifecycle as they move from their founding to the period of planning for the succession. Both sector-specific development of management and organizational models and also the problems of obtaining access to international markets are also investigated. Alongside this, the foundations of a generally valid business model for service companies are described and key criteria are defined.</td>
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<tr>
<td></td>
<td>Continuation, reuse, demolition / new construction - stakeholders, goals and conflicting goals</td>
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<td>Literature</td>
<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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<td>Literature recommendations at <a href="http://www.bauprozess.arch.ethz.ch">www.bauprozess.arch.ethz.ch</a> and <a href="http://www.kompetenz.arch.ethz.ch">www.kompetenz.arch.ethz.ch</a></td>
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</table>

**Module 2: Acquisition**
Only for CAS ARC in Unternehmensführung und MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Competence, communication and network

Objective
The aim is to become able to analyse and implement the processes and instruments used for acquisition in one’s own company.

Content
Acquisition represents a separate project in entrepreneurial activity, since all the activities involved in obtaining a commission fall under this term. The “acquisition” module focuses on imparting basic knowledge of networking and professional dialogue. Both of these tools require an assessment of one’s own situation with regard to competence, resources and customer relations. The conversation is a direct interaction: everyone involved is both an addressee and also basically an equal interlocutor. Networking can be learned: situational “small talk,” social competence and a healthy ability to communicate can be learned.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Script notes, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

**Module 3: Marketing**
Only for CAS ARC in Unternehmensführung und MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Planning, positioning and identity

Objective
The aim is to become familiar with the tools used in marketing and able to use them in specific situations.

Content
Marketing means orienting company activities towards market demands. Communication between suppliers, clients and the competition plays the decisive role here. The “marketing” module illustrates the foundations of marketing planning for architects and engineers. The essential definitions are provided and the core tasks involved in marketing are described. On this basis, the way in which a marketing plan is developed is explained and strategic and operational marketing planning is described in detail. The topics of branding and the opportunities represented by press and public relations work for architects and planners round out the “marketing” module.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

**Module 4: Financial Management**
Only for CAS ARC in Unternehmensführung und MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Competence, communication and network

Objective
The aim is to become able to analyse and implement the processes and instruments used for acquisition in one’s own company.

Content
Acquisition represents a separate project in entrepreneurial activity, since all the activities involved in obtaining a commission fall under this term. The “acquisition” module focuses on imparting basic knowledge of networking and professional dialogue. Both of these tools require an assessment of one’s own situation with regard to competence, resources and customer relations. The conversation is a direct interaction: everyone involved is both an addressee and also basically an equal interlocutor. Networking can be learned: situational “small talk,” social competence and a healthy ability to communicate can be learned.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

**Module 5: Life Cycle and Resources**
Does not take place this semester.
Only for CAS ARC in Real Estate Strategies urban peri-urban and MAS in Architecture, Real Estate, Construction.

Abstract
Key words: building fabric, material cycle
Reusability of building fabric, energy flows, pollutants

Objective
Building and breaking off is understood as an energy and material flow.

Content
The total weight of all properties in Switzerland is estimated at around 1 billion tonnes. Every year around 10 million m³ of buildings are demolished and more than 60 million t of raw materials are used in new buildings. This module examines the cycle principle and its implications for selective decommissioning, disposal, landfilling, recycling and reuse, as well as the importance of the gray matter energy of materials.

Lecture notes
Continuation, reuse, demolition / new construction - stakeholders, goals and conflicting goals

Literature
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch
Abstract
Key terms: Cost accounting, budgeting and controlling

Objective
The aim is to become able to analyse one’s own company’s financial resources in detail, interpret key parameters for the current situation and test them.

Content
Financial management means achieving the target company output with costs that are as low as possible, and in the longer term to create secure asset and capital structures. The tasks involved in financial management in a planning office include establishing a well-structured accounting department, careful cost accounting, sound budgeting and an effective controlling system. On the basis of a practical financial structure for architecture and engineering offices, the “financial management” module presents the information needed to carry these tasks out in a professional and responsible way.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

072-0405-00L Module 5: Digitalisation
Only for CAS ARC in Unternehmensführung and MAS in Architecture, Real Estate, Construction.

Abstract
Key terms: Strategy, potentials and digital planning

Objective
The aim is to become familiar with the current practical work involved in IT in planning companies and be able both to analyze the specific challenges it implies and also to infer one’s own prospects for development in this context. In addition, thought needs to be given to the way in which the value creation provided by digitalisation influences one’s own company.

Content
IT refers on the one hand to information and data processing in a company, and on the other to the hardware and software components needed for the purpose. This “information technology” module focuses on potential strategies for company management in the IT field. The focus is not on the use of any individual programme, but on taking conscious decisions for or against IT components in one’s own company in order to obtain helpful support in one’s everyday work. The strengths, weaknesses, opportunities and risk of this strategy suggest possible potentials.

The participants will present their own theses on entrepreneurship and open them up for discussion in the plenary session.

Lecture notes
Scripts, documents, studies, dates and addresses are stored on the server of the program.

Literature
Literature recommendations at www.bauprozess.arch.ethz.ch and www.kompetenz.arch.ethz.ch

Term Paper
The Term Paper is offered in spring semesters only.

MAS in Architecture, Real Estate, Construction - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Advanced Training Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>865-0065-00L</td>
<td>VET between Poverty Alleviation and Economic Development</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>K. Hartgen, F. Kehl, M. Maurer</td>
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<tr>
<td></td>
<td>Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation.</td>
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<td></td>
<td>ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.</td>
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<td></td>
<td>Registration only through the NADEL administration office.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>The course aims at strengthening the capacity in portfolio management for VET, skills development and active labor market policies. It deals with basic issues and challenges of Vocational Education and Training (VET) in Developing Countries. In view of the many of school leavers VET has to place itself between the contradicting intensions of quality education and short-term training interventions.</td>
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<td></td>
<td>Objective</td>
<td>The participants are able to</td>
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<tr>
<td></td>
<td>- Assess project portfolio, past and ongoing project regarding their relevance and suitability in the specific country context</td>
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<td></td>
<td>- Explain strengths and weaknesses of the opposing approaches &quot;dual apprenticeship&quot; and &quot;competency based training&quot; as well as synergies and incompatibilities between the two</td>
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<tr>
<td></td>
<td>Content</td>
<td>- Basic concepts and terms</td>
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<td>- Differences and commonalities between VET and neighboring systems</td>
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<td>- Planning, assessment of VET interventions with different objectives: economic development, poverty alleviation, creation of self-employment or systems development</td>
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<td></td>
<td></td>
<td>- VET as a cooperation system of stakeholders with different duties, interests and competencies</td>
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<td></td>
<td>- Background, potential use and limitations of (national) qualification frameworks</td>
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<tr>
<td></td>
<td></td>
<td>- Half-day visit to important actors of the Swiss VET landscape</td>
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<td></td>
<td>Prerequisites / notice</td>
<td>Students of the course must fulfill requirements specified on the homepage of NADEL. Electronic registration may be done only after registration with NADEL secretariate.</td>
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<tr>
<td>865-0000-06L</td>
<td>Impact Evaluations in Practice</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>I. Günther, A. Rom, K. Schneider</td>
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<td></td>
<td>Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation.</td>
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<td></td>
<td>ETH doctoral students working on topics related to poverty reduction in low- and middle income countries may also be admitted.</td>
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<td>Registration only through the NADEL administration office.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td>The course gives an introduction to the most important methods for rigorous impact analysis of development programs and projects. The course is designed to both cover the most fundamental methods of impact analysis and introduce real world case studies from national, international and non-governmental development organizations and asks how rigorous impact analysis has influenced their policies.</td>
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<td></td>
<td>Objective</td>
<td>Participants understand the most important methods of impact analysis. They are able to conduct small scale studies to evaluate the impact of their own programs as well as manage larger impact evaluations for their organizations. Participants are able to use the results of own and external impact studies.</td>
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<td></td>
<td>Content</td>
<td>Introduction to rigorous impact analysis; Case studies and their policy implications; Introduction to the required statistical knowledge; Potentials and limitations of quantitative analysis; Experimental and quasi-experimental methods; Relevant and feasible indicators for the measurement of outcomes and impacts; Data collection and analysis; Project management of an impact analysis.</td>
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<td></td>
<td>Abstract</td>
<td>The course conveys basic knowledge of methods and instruments for the financial management and the economic analysis of development projects. Case studies and exercises are used to make students familiar with methods and instruments of financial management.</td>
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<td>Objective</td>
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<td>Prerequisites / notice</td>
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<tr>
<td>865-0064-00L</td>
<td>Decolonizing Aid</td>
<td>W</td>
<td>2 credits</td>
<td>3G</td>
<td>K. Schneider, L. Hensgen</td>
</tr>
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<td></td>
<td>Only for MAS/CAS in Development and Cooperation students, as well as specialists with at least 24 months of practical experience in international cooperation.</td>
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<td>Doctoral students dealing with empirical research in the area of development and cooperation (EZA) may be admitted &quot;sur Dossier&quot;.</td>
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<td>Registration only through the NADEL administration office.</td>
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</table>
The course is designed to increase awareness of how cultural perceptions and power structures have influenced society and our understanding of and practice in aid. It promotes alternatives to aid as linear and progressive Eurocentric narrative. The course draws on different theoretical perspectives and scrutinizes practical examples of aid interventions and similar initiatives.

**Objective**
The course goes beyond awareness raising of personal cultural characteristics and recognizing cultural values within development concepts. It unfolds traces of colonialism and power structures in day to day live and the aid industry. It promotes searching and initiating alternatives to aid as a Eurocentric narrative. Participants get familiar with different theoretical perspectives on decoloniality and scrutinize practical examples of aid interventions and similar initiatives.

**Content**
- Decolonialism key terms and concepts
- Conceptions of and alternatives to development (cooperation)
- Cultural (self-) awareness, diversity
- The role of culture in aid / development cooperation
- Implications of decolonialism for aid policy making and practice

**Study Semester**

**Compulsory Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>865-0001-00L</td>
<td>Cultural and Social Aspects of Development</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>C. Humphrey</td>
</tr>
</tbody>
</table>

This two-day course demystifies impact investing for people working in development cooperation. The course provides an introduction to the terminology and instruments involved in impact investing and evaluating opportunities and trade-offs for development.

**Objective**
This two-day course demystifies impact investing for people working in development cooperation. Impact investing—the idea that it is possible to “do good” as well as make money with certain types of investment—is changing the landscape of development cooperation. Impact investing is growing rapidly and development agencies and non-governmental organizations increasingly seek to leverage private investor resources. But many development actors are not accustomed to working with private investors, and are uneasy about their profit motivation and modes of operation. The course provides an introduction to the terminology and instruments involved in impact investing and evaluates developmental opportunities and trade-offs.
Abstract
In this course, central development issues are discussed from a historical, sociological, and anthropological perspective. Themes such as
decolonization, migration, gender, racism, religion and education are used to shed light on one's own Western ideas and critically reflect on
their influence on the design of interventions in development cooperation.

Objective
The students will be able to
- consider which social, cultural and psychological factors influence human action, and discuss their importance for development cooperation
- explain different conceptions of development in Western and non-Western cultures and indicate possible consequences for development projects
- display basic knowledge of selected topics on social and cultural development

Content
Raising awareness on selected cultural and social aspects of development issues and their relevance for development cooperation (DC):
- Importance of the concept of "culture" in DC
- Colonialism, decolonization and its consequences
- Promotion of education systems
- Role of religion in development interventions
- Migration - challenges and opportunities
- Cross-cutting issues in DC: gender and disability
- Art and peacebuilding

865-0003-00L Development Economics  O   3 credits  3G  I. Günther
Does not take place this semester.
Only for MAS in Development and Cooperation.

Abstract
This course presents the origins and evolution of the International Development Cooperation during the last six decades and relates the changing paradigms to their political and socio-economic contexts. It looks at the different actors with their specific roles, approaches and challenges from a Swiss as well as a global perspective.

Objective
The students are able to...
- analyse the evolution of the International Development Cooperation, selected development theories and their practical application in the historic context
- describe the Swiss landscape of actors in Development Cooperation and its integration into the international community of donors.
- assess possible implications of the Agenda 2030 for the structure and practice of the international cooperation

Content
- History of international Development Cooperation: beginnings, change of development theories over time
- International efforts to increase sustainability and aid effectiveness
- Swiss bilateral agencies for development: SDC and SECO
- Multilateral development banks: Bretton Woods Institutions
- Non-governmental Organisations: Challenges today - in Switzerland and in partner countries
- Economy, private foundation and philanthropy: New actors with high aspirations
- Humanitarian Aid between intervention in crises, prevention and development tasks

865-0007-00L History and Forms of International Development  O   3 credits  3G
Does not take place this semester.
Only for MAS in Development and Cooperation.

Abstract
This course focuses on selected issues of governance systems in developing countries, and on possible interventions of development cooperation to improve the quality of governance.

Objective
The course introduces students to the basics of governance systems in developing countries and to possible interventions of development cooperation to improve the quality of governance.

865-0001-00L Politics and Governance  O   2 credits  2G
Does not take place this semester.
Only for MAS in Development and Cooperation.

Abstract
Degradation of the environment and non-sustainable use of natural resources, including land, water, forests and biodiversity is threatening individual livelihoods as well as local, national and international economies. This lecture series will address conflicts related to unsustainable resource use and discuss trade-offs between environmental sustainability and economic development.

Objective
The student will be able to
- describe the current status and threats of natural resource use and environmental degradation
- portray the management of natural resources such as land, forest, water, and biodiversity in different contexts and discuss the key challenges in each sector
- examine the implications of climate change on development and the sustainable management of natural resources
- analyze conflicts and trade-offs between natural resource use and economic development
- discuss the global priorities related to human-induced changes to the environment, and how these can be met

Electives

Number  Title  Type  ECTS  Hours  Lecturers
865-0010-02L  Food Security and Agriculture  W   2 credits  2G
Does not take place this semester.
Only for MAS in Development and Cooperation.

Abstract
Food security has been on top of the policy agenda for decades, but still a considerable proportion of the population in developing countries remains hungry and malnourished. This lecture series will explore how we produce and distribute food; analyze the concept of food security and discuss ways and means for increasing the availability and accessibility of food in developing countries.
Objective

The student will be able to
- describe the most important milestones in the history of food and agriculture
- understand the concept of food security and discuss causes and impact of food insecurity
- compare different approaches to promote and increase crop- and livestock production in a sustainable manner
- reflect on some of the main economic challenges of the world food system and understand some of the tradeoffs between smallholders’ decisions of labor, consumption, and production of food
- give insights in how international organizations work with farmers and governments in developing countries to ensure availability and equal access to food

Semester Thesis

Number Title Type ECTS Hours Lecturers
865-0700-00L Semester Thesis O 4 credits 9A Lecturers

Abstract

The students work on a question in multidisciplinary groups applying theory-based approaches and sound methods. The results are discussed with experts and policymakers. The thesis is a literature study with a strong application-oriented or empirical character based on scientific publications, expert opinions and reports from organizations. The work may also include limited information surveys.

Objective

- Practice scientific collaboration in a multidisciplinary team
- Apply themselves to a development topic in order to address policy relevant questions
- Present and discuss study results and policy implications in front of different audiences
### MAS in Development and Cooperation - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Key for Type</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-  Recommended, not eligible for credits</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z  Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr  Suitable for doctorate</td>
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### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS** European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

Permission from lecturers required for all students. Number of participants limited to 15.

The course is open to Master and MAS students in food and science and nutrition or related. Basic knowledge of food chemistry and nutrition is expected, as well as an understanding of food processing.

The cooking and laboratory methods will be described in the "script" which will be made available before the start of the course.

Students should be able to
- describe and compare the major concepts / criteria used for the evaluation of the nutritional quality of food
- apply these criteria when assessing the effects of selected processing technologies on nutritional quality.
- evaluate recent formulation strategies aimed to achieve additional physiological benefits for targeted population groups (i.e. functional foods).

The course gives inputs on compositional changes in food due to processing (with focus on thermal/chilling, enzymatic, chemical, emerging technologies) or new formulation strategies. Possible evaluation methods for these changes (e.g. nutritional profile) will be addressed.

There is no script. Powerpoint presentations and relevant scientific articles will be available online for students. A selection of recommended readings will be given at the beginning of the course.

The nutritional values of the meals are discussed, as well as their relation to specific chronic diseases and iron bioavailability. Discussion is EbisPro and then critically evaluated.

Analytical methods. The analytical results are compared with calculated data from food composition databases using the nutrition software of macronutrients, specific micronutrients and secondary plant components (polyphenols and phytic acid) are analysed using common analytical methods. The analytical results are compared with calculated data from food composition databases using the nutrition software of macronutrients, specific micronutrients and secondary plant components (polyphenols and phytic acid) are analysed using common analytical methods. The analytical results are compared with calculated data from food composition databases using the nutrition software of macronutrients, specific micronutrients and secondary plant components (polyphenols and phytic acid) are analysed using common analytical methods. The analytical results are compared with calculated data from food composition databases using the nutrition software.

Based on these results, the nutritional value of each meal is critically evaluated and discussed.

The nutritional values of the meals are discussed, as well as their relation to specific chronic diseases and iron bioavailability. Discussion is facilitated by an oral presentation with colloquium and a written report.

The practical course is accompanied by lectures on the basic principles of analytical chemistry that will be made available via Moodle.

The cooking and laboratory methods will be described in the "script" which will be made available before the start of the course. All lectures will have full notes and a recording made available via Moodle.
This course will familiarise students with the fundamental concepts, methodologies and terminology that apply to human nutrition research.

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including Type 2 diabetes, C. Hartmann, M. Siegrist

3 credits

Hours

assessed

W+

Problem-solving

2V

Food Law and Legislation

Food and Consumer Behaviour

Lecturers

Lecture slides and required handouts will be available on the ETH website (moodle).

The course introduces basic concepts of the interaction between nutrition and exercise performance.

The course will cover elementary aspects of sports nutrition physiology, including carbohydrate, glycogen, fat, protein and energy metabolism. A main focus will be to understand nutritional aspects before exercise to be prepared for intensive exercise bouts, how exercise performance can be supported by nutrition during exercise and how recovery can be assisted by nutrition after exercise. Although this is a scientific course, it is a goal of the course to translate basic sports nutrition science into practical sports nutrition examples.

2 credits

There is no script. Powerpoint presentations will be made available on-line to students.

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

The course is designed for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

2 credits

The course provides students interested in nutrition with fundamental tools and concepts in human nutrition research, including topics such as study design, statistical analysis, scientific writing and communicating results. Preparation of a research proposal will consolidate student learning.

The course features both didactic presentations and in-class practical exercises including topics such as study design, statistics, scientific writing and communicating results. Students will have the opportunity to consolidate their learning by preparing a research protocol to study a nutrition-related health problem, which will be submitted for grading and presented in an end-of-semester graded poster presentation.

The course is for 3rd year Bachelor students, Master students and postgraduate students (MAS/CAS).

It is strongly recommended to attend the lectures. The lecture (including the handouts) is not designed for distance education.

2 credits

Table of Domain A - Subject-specific Competencies

<table>
<thead>
<tr>
<th>Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A: Subject-specific Competencies</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
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| Domain B: Method-specific Competencies | Problem-solving | Project Management | assessed | assessed |
| Domain D: Personal Competencies | Creative Thinking | Critical Thinking | assessed | assessed |

**Electives**

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>752-2122-00L</td>
<td>Food and Consumer Behaviour</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>M. Siegrist, C. Hartmann</td>
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<tr>
<td>752-0801-00L</td>
<td>Food Law and Legislation</td>
<td>W</td>
<td>1 credit</td>
<td>1V</td>
<td>C. Spinner, E. Zbinden Kaessner</td>
</tr>
</tbody>
</table>
Introduction into structural and functional aspects of the immune system. Knowledge of the principles and the structure of the EU in general and in the area of food safety, overview of the relevant bilateral agreements CH-EU as well as on the most important international organisations (Codex Alimentarius and WTO) and their influence on the Swiss regulations on food safety.

General introduction into the EU and in the area of food safety (regulation on food safety), legislative procedures in the EU, introduction into the relevant bilateral agreements CH-EU, introduction into international organisations (e.g. Codex Alimentarius), general principles of the Swiss food law and the most important regulations as well as the most important legal procedures, legal settlement and the duties and responsibilities of the Food control authorities.

Lecture notes
Copies of the presentations will be handed out.

Literature
Documents about Codex Alimentarius, the EU regulation as well as the Swiss food law and some regulations will be handed out.

Prerequisites / notice
Qualifications: General knowledge of the food sciences.
The lecture will be held in German.

575-5103-00L Functional Microorganisms in Foods W 3 credits 2G C. Lacroix, A. Geimnaert, A. Greppi

Abstract
This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

Objective
To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

Content
This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- Legal and protection issues related to functional foods
- Industrial biotechnology of flavor and taste development
- Safety of food cultures and probiotics

Lecture notes
Copy of the power point slides from lectures will be provided.

Prerequisites / notice
This lecture requires strong basics in microbiology.

575-5111-00L Gene Technology in Foods W 3 credits 2V F. Constancias, G. Broggni, A. Greppi, F. Orelli

Abstract
This course will increase basic knowledge on biotechnological constructions and application of genetically modified organisms (GMO) which are used worldwide in food production systems. The course discusses health issues, the legislation frame and food safety aspects of GMO applications in agriculture, food production and consumption in Switzerland and EU-countries.

Objective
This course will provide knowledge and biological background on genetically modified organisms (GMO) and food produced with the help of GMO, especially on the molecular basis of GMO constructions with emphasis on genetically modified food in Switzerland and the EU. Criteria of rationale food safety and health assessment in agriculture and food consumption will be elaborated.

Content
Overview on application in gene technology, the gene transfer potential of bacteria, plants and other organisms and the mostly used transgenes in food used as GMO used for food production and their detection technologies in food; food safety assessment of GMO food; information on the legislation in Switzerland and EU-countries

Lecture notes
Copy of the power point slides from lectures will be provided.

Prerequisites / notice
Good knowledge in biology, especially in microbiology and molecular biology are prerequisites.

Some contents will be provided by registred students who will present as a group an actual publication.

551-0317-00L Immunology I W 3 credits 2V M. Kopf, A. Oxenius

Abstract
Introduction into structural and functional aspects of the immune system.

Objective
Basic knowledge of the mechanisms and the regulation of an immune response.

Content
- Introduction and historical background
- Innate and adaptive immunity, Cells and organs of the immune system
- B cells and antibodies
- Generation of diversity
- Antigen presentation and Major Histoincompatibility (MHC) antigens
- Thymus and T cell selection
- Autoimmunity
- Cytotoxic T cells and NK cells
- Th1 and Th2 cells, regulatory T cells
- Allergies
- Hypersensitivities
- Vaccines, immune-therapeutic interventions

Literature
- Kuby, Immunology, 9th edition, Freemen + Co., New York, 2020

Prerequisites / notice
For D-BIOL students Immunology I (WS) and Immunology II (SS) will be examined as one learning entity in a "Sessionsprüfung". All other students write separate exams for Immunology I and Immunology II. All exams (combined exam Immunology I and II, individual exams) are offered in each exam session.
The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and theories of public health.

Handouts are provided to students in the classroom.

On completion of this course students will be able to demonstrate:

2. Thorough knowledge and critical awareness of current recommendations for physical activity, and current prevalence and trends of physical activity and associated diseases.
3. Awareness of current national and international physical activity policies and how these impact on global challenges.

Courses

**Public Health Concepts**

- Domain A - Subject-specific Competencies: Concepts and Theories, assessed
- Domain B - Method-specific Competencies: Analytical Competencies, not assessed
- Domain C - Social Competencies: Communication, not assessed
- Domain D - Personal Competencies: Adaptability and Flexibility, not assessed

**Translational Science for Health and Medicine**

- Domain A - Subject-specific Competencies: Concepts and Theories, assessed
- Domain B - Method-specific Competencies: Analytical Competencies, assessed

**Physical Activities and Health**

- Physical activity assessment
- Physical activity policies
- Physical activity and all cause morbidity and mortality
- Physical activity and associated diseases
- Physical activity policies
- Physical activity assessment

Courses

**Translational Science for Health and Medicine**

- Domain A - Subject-specific Competencies: Concepts and Theories, assessed
- Domain B - Method-specific Competencies: Analytical Competencies, assessed
- Domain C - Social Competencies: Communication, not assessed
- Domain D - Personal Competencies: Adaptability and Flexibility, not assessed

**Physical Activities and Health**

- Physical activity assessment
- Physical activity policies
- Physical activity and all cause morbidity and mortality
- Physical activity and associated diseases
- Physical activity policies
- Physical activity assessment
Core texts for this course are:

Selective journal articles from relevant journals such as Journal of Physical Activity and Health and Journal of Aging and Physical Activity

From the BSc-course the following book is recommended: ‘Essentials of strength training and conditioning’ T. Baechle, R. Earle (3rd Edition)

**Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>766-6500-00L</td>
<td>MAS Master’s Thesis</td>
<td>O</td>
<td>20</td>
<td>43D</td>
<td>Lecturers</td>
</tr>
<tr>
<td></td>
<td>Only for MAS in Nutrition and Health.</td>
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</tbody>
</table>

**Abstract**
The study program is completed with the Master thesis, an independent scientific work. Topics are selected within the domains of the MAS program. The work is supervised by a lecturer of the MAS program.

**Objective**
The Master thesis must demonstrate the student’s ability to independent, structured and scientific working.

### MAS in Nutrition and Health - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

<table>
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<th>Letter</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

### ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Fire Safety Engineering
Four-semester, part-time MAS programme, starting in autumn semester (even years).

Next start: Autumn Semester 2022

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>121-0100-00L</td>
<td>Module 1: Fire Science</td>
<td>O</td>
<td>10 credits</td>
<td>9G</td>
<td>A. Frangi</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester.</td>
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<td></td>
<td>Only for MAS ETH in Fire Safety Engineering.</td>
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<tr>
<td>121-0110-00L</td>
<td>Module 2: Fire Safety Design</td>
<td>O</td>
<td>10 credits</td>
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<td>Does not take place this semester.</td>
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<tr>
<td>121-0140-00L</td>
<td>Module 5: Fire Protection Systems</td>
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<td>6 credits</td>
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</table>

MAS in Fire Safety Engineering - Key for Type

| O  | Compulsory                          | E-  | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended| Z   | Courses outside the curriculum       |
| W  | Eligible for credits                | Dr  | Suitable for doctorate               |

Key for Hours

| V  | lecture                             | P   | practical/laboratory course         |
| G  | lecture with exercise               | A   | independent project                 |
| U  | exercise                            | D   | diploma thesis                      |
| S  | seminar                             | R   | revision course / private study     |
| K  | colloquium                          |     |                                      |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Building Process Leadership

The MAS in "Gesamtprojektleitung Bau" is of a duration of 2 years, starting in autumn semester (n-service).

Start of the next course: Autumn Semester 2021

Module

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>067-0101-00L</td>
<td>Involved Parties</td>
<td>O</td>
<td>10 credits</td>
<td>21G</td>
<td>A. Paulus</td>
</tr>
</tbody>
</table>

Abstract
Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Objective
The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.
- Expertise and personal skills
- Organisational forms and SWOT analysis
- Role, contracting and authority to issue directives
- Responsibility
- Leadership

Content
Our advanced studies' lectures are given in German. Please find an English written abstract and/or keywords in the field 'objective'.

Lecture notes
Please find the teaching material, the further readings and Information on our server.

Literature
www.map.arch.ethz.ch/en

Teaching competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
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<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

| Domain C - Social Competencies          |             |          |
| Communication                           | assessed    |
| Cooperation and Teamwork                | assessed    |
| Customer Orientation                    | assessed    |
| Leadership and Responsibility           | assessed    |
| Self-presentation and Social Influence  | assessed    |
| Sensitivity to Diversity                | assessed    |
| Negotiation                             | assessed    |

| Domain D - Personal Competencies        |             |          |
| Adaptability and Flexibility            | assessed    |
| Creative Thinking                       | assessed    |
| Critical Thinking                       | assessed    |
| Integrity and Work Ethics               | assessed    |
| Self-awareness and Self-reflection      | assessed    |
| Self-direction and Self-management      | assessed    |

Interests

<table>
<thead>
<tr>
<th>Number</th>
<th>Interests</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>067-0103-00L</td>
<td>Interests</td>
<td>O</td>
<td>10 credits</td>
<td>11G</td>
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</table>

Abstract
In our third semester, we reconsider and re-evaluate our identity as a leading consultant. For this we see how the concept of leadership works on and shapes our skills. In line with our acquired knowledge we now pay attention to all involved interests: the perception of demand. Furthermore, it is a necessity to understand the tasks and duties of every role which you can take on.

Objective
The students are able to understand the following terminologies, processes and competences. They are able to put them into practice.
- Interests and positions, perception of demands
- Concept of leadership
- Construction industry and real estate market

Content
In our third semester, we reconsider and re-evaluate our identity as a leading consultant. For this we see how the concept of leadership works on and shapes our skills. In line with our acquired knowledge we now pay attention to all involved interests: the perception of demand. Furthermore, it is a necessity to understand the tasks and duties of every role which you can take on.

Literature
www.map.arch.ethz.ch/en

MAS in Building Process Leadership - Key for Type

| O       | Compulsory                                   | E-       | Recommended, not eligible for credits |
| W+      | Eligible for credits and recommended         | Z        | Courses outside the curriculum         |
| W       | Eligible for credits                         | Dr       | Suitable for doctorate                  |

Key for Hours

| V       | lecture                                      | P        | practical/laboratory course             |
| G       | lecture with exercise                        | A        | independent project                     |
| U       | exercise                                     | D        | diploma thesis                          |
| S       | seminar                                      | R        | revision course / private study          |
| K       | colloquium                                   |          |                                          |

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in History and Theory of Architecture (GTA)

The MAS-programm in "History and Theory of Architecture" is a two-year half-time course and contains 60 CP. The course starts in the autumn semester.

Attendance of classes supplemented by independent research; practical training periods and excursions; lectures/seminars on one to two days per week, in total 600 ca. contact hours, in addition private study ca. 600 hours (for each in-class day one day of work preparation), two individually tutored seminar papers on chosen subjects (200 hours) and credited Master's thesis (600 hours).

1. Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0001-01L</td>
<td>Architecture and the City I</td>
<td>O</td>
<td>4</td>
<td>4S</td>
<td>S. Schindler Kilian, A. J. Bideau</td>
</tr>
<tr>
<td>Abstract</td>
<td>Land and the ways in which humans divide, construct, and value it exert a profound influence on architecture and building activity. Conversely, architecture shapes how land, a limited resource, is allocated—often in unequal terms. This leads to conflicts, for instance in the urban realm. What is the role of architectural criticism in negotiating these kinds of conflicts?</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Students gain an understanding of different approaches to architectural criticism. They write and revise their own texts in short, middle and long form, and also edit their peers' work.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Analysis of key texts; site visits of current building and planning projects; weekly writing assignments; reviews and lectures with invited critics from general-audience and professional publications.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Will be posted on the MAS platform.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prequisites / notice</td>
<td>None.</td>
<td></td>
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</table>

Workshop

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0005-01L</td>
<td>Methods of Academic Writing I</td>
<td>O</td>
<td>1</td>
<td>3U</td>
<td>S. Schindler Kilian, M.-A. Lerjen</td>
</tr>
<tr>
<td>Abstract</td>
<td>Through hands-on teaching, the methods workshops introduce students to the various approaches to academic writing in the humanities and convey the methodological foundations of architectural history. Lecturers and students discuss and work on research papers and master's theses as well as the group's research project.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Students learn to identify and apply different methods of academic writing in architectural history. They acquire the ability to recognize and independently solve problems related to research and writing.</td>
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</table>

Essays

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0201-01L</td>
<td>Scientific Home Work (1)</td>
<td>O</td>
<td>4</td>
<td></td>
<td>S. Schindler Kilian, M. Delbeke</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students write a seminar paper on a subject of their choice in consultation with a lecturer, developing the skills to pursue independent academic work.</td>
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<tr>
<td>Objective</td>
<td>Students write an academic paper of approx. 3.000 words/20.000 characters.</td>
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</table>

3. Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0003-01L</td>
<td>Architecture and the City III</td>
<td>O</td>
<td>4</td>
<td>4S</td>
<td>S. Schindler Kilian, A. J. Bideau</td>
</tr>
<tr>
<td>Abstract</td>
<td>Land and the ways in which humans divide, construct, and value it exert a profound influence on architecture and building activity. Conversely, architecture shapes how land, a limited resource, is allocated—often in unequal terms. This leads to conflicts, for instance in the urban realm. What is the role of architectural criticism in negotiating these kinds of conflicts?</td>
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<tr>
<td>Literature</td>
<td>Will be posted on the MAS platform.</td>
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<tr>
<td>Prequisites / notice</td>
<td>None.</td>
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Workshop

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>056-0009-01L</td>
<td>Architecture and the City V</td>
<td>W</td>
<td>4</td>
<td>9S</td>
<td>S. Schindler Kilian</td>
</tr>
<tr>
<td>Abstract</td>
<td>&quot;Architecture and the City V&quot; serves as the container to register in the transcript the two electives at 2 credit points each which are required from MAS gta students for their degree. Students should register both for this course and for the electives.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The goal of requiring two electives is to expose MAS gta students to the range of content and methods being taught at gta/DARCH.</td>
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Workshop

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0007-01L</td>
<td>Research Methods in the History and Theory of Architecture</td>
<td>O</td>
<td>1</td>
<td>3U</td>
<td>C. Rachele, S. Schindler Kilian</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to methodological approaches in the history and theory of architecture; presentation and discussion of individual projects.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The course in the first year of the doctoral program in the history and theory of architecture has a twofold objective: First, method sessions on central approaches in the history and theory of architecture provide a methodological basis for the doctorate at the Institute gta. Secondly, in toolkit and review sessions, the doctoral students get support for their individual research projects and guidance for the production of the Research Plan they have to present at the end of the first year.</td>
<td></td>
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</tbody>
</table>
The seminar course prepares the doctoral students for their Research Plan submission at the end of their first year. The weekly seminar will frame group discussions on a variety of topics, group presentations, and preparatory exercises. Students are encouraged to consider the course readings not only in terms of their content, but also as illustrations of formatting, structuring and argumentation methods, that can serve as research models.

There are four types of seminar classes. Toolkit classes focus on the individual components of the Research Plan: abstract, hypothesis, literature survey, research structure etc. Method classes cover research strategies and disciplinary traditions relevant for doctoral studies in the history and theory of architecture. Theory seminars focus on specific intellectual traditions and their comparison. The in-seminar Review sessions, leading up to the formal end-of-semester Doctoral Reviews with external guests, comprise work-in-progress presentations and peer-review appraisals.

The course schedule will be available at the beginning of HS 2021 on the course website:

Lecture notes
Scans of selected texts for discussion and exercises will be provided at the beginning of HS 2021 on the course website:

Literature
The following titles offer background and detailed information regarding research methodologies for a variety of disciplines.


Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>056-0210-01L</td>
<td>MAS Thesis Preparation</td>
<td>O</td>
<td>5 credits</td>
<td>9A</td>
<td>S. Schindler Kilian, M. Delbeke</td>
</tr>
</tbody>
</table>

Abstract
This one-semester module is dedicated to identifying the topic for the Master's thesis and developing the research plan. The Master's thesis itself is written in the following spring semester.

Objective
The aim is to develop a relevant hypothesis and research question for the Master's thesis that is based on an analysis of the current state of the field. Additionally, the research plan includes preparing an annotated bibliography, elaborating the methodological approach and a timeline of deliverables.

Content
The topic of the MAS master thesis is chosen by the students and further refined through individual consultation with the docents. At the end of the semester, the students present their research plan to external guest critics. The research plan comprises about 25,000 characters.

Literature
See internal MAS platform

MAS in History and Theory of Architecture (GTA) - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>Item</th>
<th>Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th></th>
<th>Item</th>
<th>Type</th>
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<tbody>
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<td>practical/laboratory course</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Housing

1 year full time course in English, starting every autumn semester.
Further information on www.wohnforum.arch.ethz.ch

Lectures, workshops, individual and group tutorials and excursions organized in the framework of the four modules: Cultural, socio-economic, demographic and political aspects of housing and human settlements (M1); Adequate housing and neighbourhood development strategies (M2); Housing for migrants, refugees, and people displaced by disasters (M3); Housing research and evaluation methods (M4).

Introduction to the MAS Housing: Room HIT H 13 (Date and Time will follow in due time).
Presentation of MAS Thesis Proposals: Room HIT H 13 (Date and time will follow in due time).

Core Courses

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</thead>
<tbody>
<tr>
<td>Number</td>
<td>O 4 credits</td>
<td>O 4 credits</td>
<td>O 10 credits</td>
<td>O 10 credits</td>
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<tr>
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<td>J. E. Duyne Barenstein</td>
<td>J. E. Duyne Barenstein</td>
<td>J. E. Duyne Barenstein</td>
<td>J. E. Duyne Barenstein</td>
</tr>
<tr>
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<td>Only for MAS in Housing</td>
<td>Only for MAS in Housing</td>
<td>Only for MAS in Housing</td>
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<tr>
<td>Hours</td>
<td>2G</td>
<td>2G</td>
<td>2G</td>
<td>2K</td>
</tr>
<tr>
<td>Lecturers</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Globally over one billion people lack adequate housing. Meeting their</td>
<td>With the aim of understanding the role of architecture in</td>
<td>This course offers an introduction to a wide</td>
<td>The course is intended to support the students to develop their individual</td>
</tr>
<tr>
<td></td>
<td>housing needs requires innovative solutions that are affordable,</td>
<td>responding to the constantly changing housing needs and demands we</td>
<td>range of research methods currently used in</td>
<td>research proposals and to attain the necessary skills to work independently</td>
</tr>
<tr>
<td></td>
<td>inclusive, sustainable and scalable. We will critically review the</td>
<td>will visit and analyze a selected number of housing projects that</td>
<td>housing and neighbourhood studies. Students</td>
<td>and with scientific rigour on a project leading to their final MAS thesis.</td>
</tr>
<tr>
<td></td>
<td>causes and consequences of the current housing crisis and the</td>
<td>are innovative from a social, institutional and architectural</td>
<td>will be invited to reflect on the value of</td>
<td>The course is intended to support the students to develop their individual</td>
</tr>
<tr>
<td></td>
<td>various strategies through which a wide range of actors at local,</td>
<td>perspective.</td>
<td>different tools to inform evidence-based</td>
<td>research proposals and to attain the necessary skill to work independently and</td>
</tr>
<tr>
<td></td>
<td>national and international level are addressing the housing</td>
<td></td>
<td>design processes and to provide rigorous</td>
<td>with scientific rigour on a project leading to their final MAS thesis.</td>
</tr>
<tr>
<td></td>
<td>question.</td>
<td></td>
<td>answers to research question by covering all</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the steps of the research cycle.</td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>The students will learn to understand the meaning of housing in</td>
<td>The students will gain a better understanding of the socioeconomic,</td>
<td>Students will acquire the theoretical and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>relation to its broader socioeconomic, cultural, political, and spatial</td>
<td>cultural and institutional factors determining innovation in the</td>
<td>methodological skills to design and carry out</td>
<td></td>
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<tr>
<td></td>
<td>context and to critically reflect on the viability, effectiveness</td>
<td>housing sector.</td>
<td>an independent scientific research project.</td>
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<tr>
<td></td>
<td>and sustainability of different housing strategies.</td>
<td></td>
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<tr>
<td>Content</td>
<td>Housing is a human right but also one of the most daunting challenges</td>
<td>All over the world a wide range of public and private organizations</td>
<td>This course offers an introduction to a wide</td>
<td></td>
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<tr>
<td></td>
<td>of urbanisation globally. Currently over one billion people lack</td>
<td>are responding to the qualitative and/or quantitative housing</td>
<td>range of research methods currently used in</td>
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<tr>
<td></td>
<td>affordable and housing, a number that may increase to 1.6 billion</td>
<td>deficits through innovative projects. With the aim of understanding</td>
<td>housing and neighbourhood studies. Students</td>
<td></td>
</tr>
<tr>
<td></td>
<td>people within a decade. Ensuring access to adequate, safe and</td>
<td>the role of architecture in responding to the constantly changing</td>
<td>will be invited to reflect on the value of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>affordable housing to all is one of the targets of the 2030</td>
<td>societal needs and aspirations we will visit and analyze a</td>
<td>different tools to inform evidence-based</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agenda for Sustainable Development. However, this target is unlikely</td>
<td>selected number of ground-breaking housing projects. Interactions</td>
<td>design processes and to provide rigorous</td>
<td></td>
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<td></td>
<td>to be met without a radical change in housing policies and practices,</td>
<td>with relevant stakeholders will ensure students to reflect upon their</td>
<td>answers to research questions by covering all</td>
<td></td>
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<td></td>
<td>Indeed, meeting millions of people’s housing needs requires</td>
<td>innovative character from a social, institutional and architectural</td>
<td>the steps of the research cycle. Particular</td>
<td></td>
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<tr>
<td></td>
<td>innovative solutions that are inclusive, sustainable and scalable.</td>
<td>perspective.</td>
<td>emphasis will be given to qualitative and</td>
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<td></td>
<td>The course focuses on the causes and consequences of the global</td>
<td>These visits will be followed by individual and group exercises;</td>
<td>participatory research methods that will</td>
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<tr>
<td></td>
<td>housing crisis. Further it will critically reflect upon the</td>
<td>based on a common analytical framework the students will identify</td>
<td>enable the students to directly engage with</td>
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<tr>
<td></td>
<td>concept of adequate housing and on the various strategies through</td>
<td>through secondary sources additional paradigm-shifting housing</td>
<td>stakeholders, such as residents, representatives of housing and neighborhoo-</td>
<td></td>
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<tr>
<td></td>
<td>which national governments, municipalities, the private sector, and</td>
<td>projects in different parts of the world with the aim of gaining a</td>
<td>d associations, and public authorities.</td>
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<tr>
<td></td>
<td>communities in different contexts have been, or are currently</td>
<td>better understanding of the links between housing initiatives and</td>
<td>By combining theory and practice, they will</td>
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<tr>
<td></td>
<td>addressing the housing question.</td>
<td>their societal context.</td>
<td>learn to apply them to a specific context and</td>
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<tr>
<td>Lecture notes</td>
<td>A reader will be distributed at the beginning of the semester</td>
<td></td>
<td>research question. Through lectures with</td>
<td></td>
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<tr>
<td></td>
<td>containing an overview of all lectures, the involved exercises, and</td>
<td>containing an overview of all lectures, the involved exercises, and</td>
<td>practical group exercises the course will</td>
<td></td>
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<tr>
<td></td>
<td>required readings.</td>
<td>required readings.</td>
<td>equip students with the required knowledge</td>
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<tr>
<td>Prerequisites / notice</td>
<td></td>
<td></td>
<td>and skills to develop an individual research</td>
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<tr>
<td></td>
<td>Course only open to students enrolled in the ETH MAS in Housing.</td>
<td></td>
<td>project that will lead to their MAS theses.</td>
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<tr>
<td>Date: 14.12.2021 12:41</td>
<td></td>
<td></td>
<td></td>
<td>Autumn Semester 2021</td>
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<tr>
<td>Page: 1366 of 2152</td>
<td></td>
<td></td>
<td></td>
<td>Page 1366 of 2152</td>
</tr>
</tbody>
</table>
Elective Courses

At least 3 elective courses for a total of 6 ECTS have to be followed by the MAS students. These can be selected from the courses offered by the Department of Architecture or from other ETH departments.

### MAS in Housing - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td></td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
<td></td>
</tr>
</tbody>
</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Mas in Management, Technology, and Economics

MAS MTEC Introductory Event for 1st Semester Students.
Monday, 20.09.2021, 16.00 - 17.15 h, HG E 1.2 (tbc)

1. Semester

Core Courses

General Management and Human Resource Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0341-00L</td>
<td>Introduction to Management</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>Z. Zagorac-Uremovic, J. O'Neil</td>
</tr>
</tbody>
</table>

Abstract
By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate routine operations in order to meet evolving customers' and societal needs. The students will achieve these goals by being able to:

- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

Objective

By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate routine operations in order to meet evolving customers' and societal needs. The students will achieve these goals by being able to:

- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

Content
This course follows a 'systemic' view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will furthermore discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between those elements and on the application of a selection of tools and methods.

Lecture notes
The content of the course will rely on different readings, cases and selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=15262

Literature
The content of the course will rely on different readings and on selected chapters of following book:

Selected readings from the book and additional learning materials will be available on the course Moodle:
https://moodle-app2.let.ethz.ch/course/view.php?id=15262

Prerequisites / notice
Throughout the course different session preparation assignments, like book chapters or case studies will be handed out to the students on moodle. This preparation is required to participate in the lectures.
The final exam of the present course is online exam.
The final exam is requested for all types of students (BSc, MSc, MAs, PhD, and Exchange students).
It is not possible to retake the exam within the same term or academic year.
We strongly recommend Exchange students to take it into consideration when selecting the courses to attend.

Taught competencies

- Domain A - Subject-specific Competencies
- Conceptual and Theoretical
- Research
- Decision-making
- Problem-solving

- Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

- Domain C - Social Competencies
- Communication
- Leadership and Responsibility
- Sensitivity to Diversity

- Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics

363-0301-00L Work Design and Organizational Change

Abstract
Good work design is crucial for individual and company effectiveness and a core element to be considered in organizational change. Meaning of work, organization-technology interaction, and uncertainty management are discussed with respect to work design and sustainable organizational change. As course project, students learn and apply a method for analyzing and designing work in business settings.

Objective

- Know effects of work design on competence, motivation, and well-being
- Understand links between design of individual jobs and work processes
- Know basic processes involved in systematic organizational change
- Understand the interaction between organization and technology and its impact on organizational change
- Understand relevance of work design for company performance and strategy
- Know and apply methods for analyzing and designing work
The course is organized in a highly interactive fashion, where discussion in class is as important as the input by the lecturer. Understanding the dynamics in organizations is helped enormously by concrete examples, which will be provided by the lecturer, by talks by guest lecturers, and also the students themselves based on their prior experience from working in various roles (as employees, volunteers, student assistants etc.). Through class discussion we aim to deepen the understanding of the themes covered in the course. The current changes in organizations brought about by Covid-19 will also be an important example which allows to illustrate and discuss many of the key concepts of the course.

Specifically, the course will cover the following topics:
- Work design: From Adam Smith to job crafting
- Effects of work design on performance and well-being
- Approaches to analyzing and designing work
- Modes of organizational change and change methods
- Balancing stability and flexibility in organizations as design criterion
- The organization-technology interaction and its impact on work design and organizational change
- Example Flexible working arrangements (e.g. home office)
- Strategic choices for work design

All through the course, students will be guided to work on their projects also, with about 25% of class time devoted to the projects. In the final session, students will present the main results of their projects and discuss main insights also across projects.

The course includes the completion of a course project to be conducted in groups of four students. The project entails applying a particular method for analyzing and designing work processes and is carried out by means of interviews and observations in companies chosen by the students.

### Strategy, Markets and Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0403-00L</td>
<td>Introduction to Marketing</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>S. Brüggemann, F. von Wangenheim</td>
</tr>
</tbody>
</table>

**Abstract**

Students who take this course will increase their knowledge of marketing, its effect on consumer behavior and its role in creating long-term value. The course will introduce important concepts, frameworks and methods for marketing decision-making. A focus will be on managing customer relationships with the help of targeted promotions and data collected through digital technologies.

**Objective**

After taking the class, students will be able to:

1) Define what marketing is and describe its role at different stages of the value chain
2) Apply psychological theories to analyze behavior (e.g., purchase behavior) and identify the needs of (prospective) customers in consumer and business markets
3) Design elements of the marketing mix—e.g., develop new products and set prices—in a way that creates long-term value
4) Create an effective and efficient marketing mix that attracts and engages customers, e.g., by running targeted promotions
5) Use quantitative methods and customer data to manage relationships with customers

**Content**

The class will center on the importance of marketing as an activity that creates long-term value for the benefit of organizations and their customers. It will teach concepts, frameworks and methods for marketing decision making.

The structure of the course will roughly follow the different steps of the value chain, i.e., the set of activities necessary for offering valuable products to customers. First, it will introduce students to psychological theories that help explain behavior, e.g., purchase behavior. It will also familiarize students with different methods from marketing research, which can be used to identify the needs of customers. Next, the course will look at the role of the marketing mix in satisfying customer needs. For example, the class will cover new product development and pricing. A focus will be on managing profitable, long-term relationships with customers. To this end, students will gain in-depth knowledge on the use of targeted promotions and marketing data to (1) attract, (2) convert and engage and (3) retain customers.

The course is designed to be "hands-on", with opportunities to apply skills on business cases involving real-world marketing data. It will feature guest lectures from industry experts.

The class might be taught in an in-person, remote or in a hybrid format.

**Literature**


### Information and Operations Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0421-00L</td>
<td>Mastering Digital Business Models</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>E. Fleisch</td>
</tr>
</tbody>
</table>

**Abstract**

This lecture provides a theory- and practice-based understanding of how today's information technologies enable new digital business models and disrupt existing markets.
Objective
A. After the lecture, the student is able to evaluate digital business models from different angles, including theory-based views:

- Definition and classification of business models
- Digital business model patterns
- Theoretical frameworks that explain why and how digital business models function
- Impact of digital business model patterns on P&L and balance sheet

Students know how to measure & evaluate investments into the digital space as

- a decision maker in an established company (should I invest in project A or B?)
- an entrepreneur (should I pursue this venture?)
- an investor (should I invest in start-up xy?)

B. The student knows different tools to design digital business model patterns.

Content
Uber, Airbnb, Nest and Jawbone - A wide range of innovative companies exist, which successfully implemented ICT enabled business models and continue to grow at a rapid pace. Examples, illustrating how digitalization, including the "Internet of Things" currently fosters business model innovation across various industries. This course is designed to help students to understand and critically assess such newly immerging (digital) business models.

Course materials will be made available on the Moodle platform through which students can solve online exercises and submit a short educational video as part of a course assignment.

Key Topics:
Business model innovation; (digital) business model patterns; business value of IT; the concept of integration; transaction cost perspective; network economics; essentials and impact of web 2.0; internet of things; mobile computing, market places, social analytics, and big data; IT governance and portfolio management; entrepreneurship in the digital space, etc.

Literature
Suggested literature is provided in the syllabus.

Quantitative and Qualitative Methods for Solving Complex Problems

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-0541-00L</td>
<td>Systems Dynamics and Complexity</td>
<td>W+</td>
<td>3</td>
<td>3G</td>
<td>F. Schweitzer</td>
</tr>
</tbody>
</table>

Objective
Finding solutions: what is complexity, problem solving cycle.

- Implementing solutions: project management, critical path method, quality control feedback loop.
- Controlling solutions: Vensim software, feedback cycles, control parameters, instabilities, chaos, oscillations and cycles, supply and demand, production functions, investment and consumption

A successful participant of the course is able to:

- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics
Why are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical systems dynamics, nonlinear dynamics and macroeconomic modeling.

The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as home work and two of these will be graded (see "Prerequisites").

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

### Micro and Macroeconomics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>363-0565-00L</td>
<td>Principles of Macroeconomics</td>
<td>W+</td>
<td>3 credits</td>
<td>2V</td>
<td>J.-E. Sturm</td>
</tr>
</tbody>
</table>

**Abstract**

This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

**Objective**

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

**Content**

This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Several examples from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption) will be used to illustrate these points.

### Literature


This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

**Number**

363-0503-00L

**Title**

Principles of Microeconomics

**Type**

W+

**ECTS**

3 credits

**Hours**

2G

**Lecturers**

M. Filippini

**Abstract**

GESS (Science in Perspective): This course is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

For students taking only the course 'Principles of Microeconomics' there is a shorter version of the same book:

Complementary:

The book can also be used for the course 'Principles of Macroeconomics' (Sturm)

Prerequisites:
- International trade
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- Public sector, tax system
- Market failures, common resources and public goods

Prerequisites / notice

Lecture notes and exercise material can be downloaded from Moodle.

The course Accounting for Managers offers an introduction to financial accounting and management accounting. It provides managers with the necessary knowledge for decision making using accounting information.

Topics covered by the course are:

- Double-entry accounting
- Financial statements
- Cost accounting
- Budgeting
- Financial management

Abstract
The course Accounting for Managers offers an introduction to financial accounting and management accounting. It provides managers with the necessary knowledge for decision making using accounting information.

Objective
By attending this course, students will be able to:
- record business transactions on the different types of accounts.
- establish a balance sheet and an income statement.
- prepare the different financial reports.
- understand the principles of cost accounting.
- determine the cost of production.
- make decisions based on cost information.

Content
The first part of the course is devoted to financial accounting. It teaches the principles of double-entry accounting and deals with the recording of commercial transactions on accounts. It describes the work to be carried out at the closing in order to prepare the financial reports according to the generally accepted accounting principles. This type of accounting information is primarily intended for investors and shareholders.

The second part of the course describes the principles of management accounting and explains the different costing methods. It aims to determine the manufacturing cost of production of the different products and services using full and variable costing methods. The accounting information focuses on the internal needs of managers for the purpose of budget preparation and profitability analysis.

Prerequisites / notice
This course is a prerequisite for the course Financial Management.
The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms competitive strategies and marketing priorities.

Core Courses

Strategy, Markets and Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0387-00L</td>
<td>Corporate Sustainability</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>V. Hoffmann, C. Bening-Bach, N. U. Blum, J. Meuer</td>
</tr>
</tbody>
</table>

Abstract
The lecture explores current challenges of corporate sustainability and prepares students to become champions for sustainable business practices. In the beginning, traditional lectures are complemented by e-modules that allow students to train critical thinking skills. In the second half of the semester, students work in teams on sustainability challenges related to water, energy, mobility, and food.

Objective
Students
- assess the limits and the potential of corporate sustainability for sustainable development
- develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method.
- recognize and realize opportunities through team work for corporate sustainability in a business environment
- present strategic recommendations in teams with different output formats (tv-style debate, consultancy pitch, technology model walk-through, campaign video)

Content
In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share their insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in one of four tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

Prerequisites / notice
TEACHING FORMAT/ ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.

363-0392-00L Strategic Management W+ 3 credits 2G Y. R. Shrestha

Abstract
This courses conveys concepts and methods in strategic management, with a focus on competitive strategy. Competitive strategy aims at improving and establishing positions of firms within an industry.

Objective
The lecture "Strategic Management" is designed to teach relevant competences in strategic planning and -implementation, for both professional work-life and further scientific development. The course provides an overview of the basics of strategy and the most prevalent concepts and methods in strategic management. The course is given as a combination of lectures about concepts/methods, and case studies where the students solve strategic issues of the case companies. In two sessions, the students will also be addressing real-time strategic issues of firms that are represented by executives.

Content

- The resource-based theory of the firm + Cases
- The knowledge-based theory of the firm + Cases
- Guest Lecture (Dr. Berg) and Introduction

Prerequisites / notice
Number of participants limited to 80. Registration through myStudies (first come, first served). We do not use the mystudies-Waiting List, and give their take on strategy in practice and give insight on current topics in the field.

Strategic Management offers a combination of lectures about concepts/methods, and case studies where the students solve strategic issues of the involved companies. This aims at offering students a profound theoretical understanding of important and current topics and also offer an opportunity to present these concepts in front of an audience.

This course conveys concepts and methods in strategic management, with a focus on competitive strategy. Competitive strategy aims at analyzing and establishing position of firms within an industry, securing firm performance. Thus, the course focuses on a number of important topics, such as the evolution of industry, industry structure, the analysis of a firm’s resources- and knowledge, and innovation.

In addition, student groups will hold presentations on the four main topics of this class, to further develop concepts and enhance understanding. The presentations will cover Industry Dynamics I, Industry Dynamics II, Resource Based View of the Firm, Knowledge Based View of the Firm. For all presentations, selected Harvard Business Cases will be used as a common ground for students to start from.

Students are also expected to read and understand the required readings (approx. 15 items) that cover the most important papers and articles from the past 30 years in management and strategy research.

To underline the relevance of Strategic Management in firms, decision makers from companies in Switzerland will be holding guest lectures and give their take on strategy in practice and give insight on current topics in the field.

For further questions and if you are unable to sign up through myStudies, please contact the course assistant:
http://www.smi.ethz.ch/education/strategic-management.html

Information and Operations Management

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>363-0453-00L</td>
<td>Strategic Supply Chain Management</td>
<td>W+</td>
<td>3</td>
<td>2G</td>
<td>S. Wagner</td>
</tr>
</tbody>
</table>

Abstract
The course offers an introduction to the theory and practice of supply chain management. Students will learn how to develop supply chain strategies and supply chain networks based on firms competitive strategies and marketing priorities.

After completing this course:
1. Students can explain the importance of supply chain management for a firm's strategy and success
2. Students are able to apply the tools and methods used to optimize a supply chain structure
3. Students can differentiate supply chain network designs and their applicability in specific company and sector settings
4. Students can describe and evaluate fundamental logistics and supply chain concepts
5. Students are able to explain elements of a supply chain structure and their importance for supply chain strategy
6. Students are familiar with current developments and trends in supply chain practices

Modern supply chains are not only essential to ensure functioning logistics but also help firms develop and maintain competitive advantage in globalized (supply) markets with numerous partners and competitors. While taking into account future opportunities and risks, effective supply chain management is inevitably cross-functional. As such, information and information infrastructure, sourcing decisions and pricing are further drivers to define a supply chain structure. Students will learn important elements in supply chain structure, including for example forecasting methods and network design modeling and optimization. Case study assignments and practical exercises within lectures allow students to gain hands-on experience and enhance their knowledge.

The wide range of topics involved in supply chain management makes the field very open to innovation and further development. In the course of the lecture, students have the chance to learn and discuss both overall trends and practical insights on development. The course furthermore encourages student involvement within lectures, in exchange with peers and with guest speakers. Case study assignments and tools for self-assessment help students to learn actively and continuously throughout the course.

The course material will be made available for download on Moodle:

https://moodle-app2.let.ethz.ch/course/view.php?id=15222

All organizational matters will be handled by the teaching assistant Sarah Schaumann (sschaumann@ethz.ch). Please use the SSSC Class Forum on Moodle as a first point of contact.

The following textbook is recommended:

The following textbook is supplementary:

Case study assignments make up 30% of the final grade. Details on submission and grading are provided within the course and on “Performance Assessment”. The maximum grade can only be achieved if both the exam is taken and all case studies are submitted.

Students should install MS Excel and the Excel Solver before class, as it is used for within-class exercises. Students without the program and add-in installed may nevertheless participate within groups during the exercises.

Transformation: Corporate Development and IT

Objective
The goal of the lecture is to understand the main challenges of corporate transformation and to demonstrate the application of a holistic project procedure model for corporate transformation projects with special emphasis on the alignment of business and IT.

Content
The lecture treats the main challenges of business transformation and the alignment of corporate development and IT activities. It presents a holistic approach to business transformation projects by introducing an integrated model dealing with three main design areas "strategy", "processes" and "information systems" and applying this model to various case studies.

The goal of the lecture is to understand the main challenges of corporate transformation and to demonstrate the application of a holistic project procedure model for corporate transformation projects with special emphasis on the alignment of business and IT.

The student should understand and be able to explain
- the main reasons for corporate transformation,
- the relevant management processes to manage corporate transformation,
- the interdependencies between strategy, processes and information systems, especially how this three levels interrelate,
- the critical success factors for the successful accomplishment of large scale corporate transformation projects,
- the main instruments of project, quality and change management and
- the different types of resulting IT projects.

The globalization of the world leads to an increasingly faster pace in business transformation. Enterprises have to adapt faster and even faster to the environmental changes in a global economy to remain competitive and to make sure they stay in business. In todays information age this does not only mean to adapt business strategy and business processes but also to adapt information systems to the new circumstances. The fast adaptation trough large scale corporate transformation projects that change strategy, business processes and information systems is critical to ensure competitiveness for tomorrow. The introduction of new business processes and information systems typically takes years in very complex large scale projects. Many projects fail because of insufficient alignment between decision makers in business and IT. Unclear understanding of the overall project scope, undefined roles and responsibilities, unclear project processes, quality problems and resistance to change are some typical problems found in such projects. The lecture is subdivided into following modules:

- Corporate development introduction and motivation,
- Parallelization of corporate development and complexity reduction,
- Planning process and project portfolio management in corporate development,
- Management of large scale projects integration of strategy, processes and information systems,
- Quality management in large scale projects,
- Project management in large scale projects,
- Change management within projects. The lecture is accompanied by four case studies that are used to exemplify the contents of the lecture by applying the concepts to real situations in corporate life.

Quantitative and Qualitative Methods for Solving Complex Problems

Number Title Type ECTS Hours Lecturers
363-0305-00L Empirical Methods in Management W+ 3 credits 2G S. Tilmanns

In this class, students learn how to understand and conduct empirical research. It will enable them to manage a business based on evidence-based decision-making. The class includes group assignments, where students will cover small parts of the lecture content in self-created videos.

The general objective of the course is to enable students to understand the basic principles of empirical studies. After successfully passing the class, they will be able to formulate research questions, design empirical studies, and analyze data by using basic statistical approaches.
Operations Research

ECTS
- Introduction to building and using quantitative models in a business / industrial environment

2G
- A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. In addition, basic statistical analyses, like a variance analysis, are considered. Often it is no longer possible to solve operational tasks with experience and common sense alone and to adequately estimate the consequences of decisions without software support.

3 credits
- Quantitative models and methods of operations research and operations management offer decision support for complex problems.

- Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be formulated and solved in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network design, airline fleet assignment and revenue management.

3 credits
- This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures.

- The following topics are covered in detail:
  - Introduction to system modelling and operations research
  - Linear models and the importance of linear programming
  - Duality theory in linear programming and shadow prices
  - Integer programming
  - Dynamic optimization (under uncertainty) and applications in inventory management.

Lecture notes
- A printed script will be made available.

Literature
- Any standard textbook in Operations Research is a useful complement to the course.

Prerequisites / notice
- Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.
Corporate Finance is an introductory course that presents those fundamental principles of finance that find direct application in the financial decisions of modern corporations. The course is structured in three parts: (i) Corporate Finance and Corporate Governance, (ii) Investment Decisions/Valuation, (iii) Financial Policy.

Content
- Corporate finance and its goals (e.g., shareholder-value approach vs. stakeholder-value approach)
- Corporate finance and corporate governance (e.g., centralized management, limited liability, free transferability of economic claims, legal personality)
- Corporate governance and its depth and then stresses how and why the theories and models fail and how this is impacting investment strategies and even a global view of citizenship, given the present developing crises in the US since 2007 and in Europe since 2010.
- Development of the concepts and tools to understand these risks and master them.

In the following, for each of the three parts of the course, key aspects, are listed.

Part I: Corporate Finance and Corporate Governance
- Corporations and their characteristics (e.g., centralized management, limited liability, free transferability of economic claims, legal personality)
- Corporate finance and its goals (e.g., shareholder-value approach vs. stakeholder-value approach)
- Corporate governance problems and possible solutions (e.g., over-investment, under-investment, self-dealing, monetary incentives, board of directors, the market of corporate control, leverage, product-market competition)

Part II: Investment Decisions/Valuation
- Discounting and compounding
- Present value tools (e.g., perpetuities, growing perpetuities, annuities, growing annuities)
- Bond pricing and interest rates (e.g., types of bonds, term structure of interest rates, yield-to-maturity, duration concepts, forward rates, "riding the yield curve")
- Risk and return (e.g., moments of stock returns, modern portfolio theory, capital market line, systematic risk vs. unsystematic risk)
- CAPM in practice (e.g., computation of the risk free interest rate, beta, and the market risk premium; security market line)
- DCF Analysis: Cost of capital and cash flow estimation
- Relative valuation (e.g., earnings multiples, book multiples, sales multiples, fundamental drivers of multiples)
- Real options (e.g., option to abandon, option to delay, option to expand)

Part III: Financial Policy
- Corporate financing (e.g., instruments, internal vs. external financing, equity financing vs. debt financing, crowdfunding, M&M and beyond)
- Payout policy (e.g., dividends, par value reductions, share buybacks, M&M and beyond)
- Discounting and compounding

For the exam, only the material provided will be relevant. However, interested students may refer to the following textbook for an alternative, or a complementary, reading:

Content

1- The Financial Crises: what is really happening? Historical perspective and what can be expected in the next decade(s). Bubbles and crashes. The illusion of the perpetual money machine.

2- Risks in financial markets
   - What is risk?
   - Measuring risks of financial assets
   - Introduction to three different concepts of probability
   - History of financial markets, diversification, market risks

3- Introduction to financial risks and its management.
   - Relationship between risk and return
   - Portfolio theory: the concept of diversification and optimal allocation
   - How to price assets: the Capital Asset Pricing Model
   - How to price assets: the Arbitrage Pricing Theory, the factor models and beyond

4- Financial markets: role and efficiency
   - What is an efficient market?
   - Financial markets as valuation engines: exogeneity versus endogeneity (reflexivity)
   - Deviations from efficiency, puzzles and anomalies in the financial markets
   - Financial bubbles, crashes, systemic instabilities

5- An introduction to Options and derivatives
   - Calls, Puts and Shares and other derivatives
   - Financial alchemy with options (options are building blocks of any possible cash flow)
   - Determination of option value; concept of risk hedging

6- Valuation and using options
   - A first simple option valuation model
   - The Binomial model for valuing options
   - The Black-Scholes model and formula
   - Practical examples and implementation
   - Realized prices deviate from these theories; volatility smile and real option trading
   - How to imperfectly hedge with real markets?

7- Real options
   - The value of follow-on investment opportunities
   - The timing option
   - The abandonment option
   - Flexible production
   - Conceptual aspects and extensions

8- Government bonds and their valuation
   - Relationship between bonds and interest rates
   - Real and nominal rates of interest
   - Term structure and Yields to maturity
   - Explaining the term structure
   - Different models of the term structure

9- Managing international risks
   - The foreign exchange market
   - Relations between exchange rates and interest rates, inflation, and other economic variables
   - Hedging currency risks
   - Currency speculation
   - Exchange risk and international investment decisions

Lecture notes
Lecture slides will be available on the site of the lecture

Literature
Corporate finance
Brealey / Myers / Allen
Eight edition

Prerequisites / notice
none

► Skill-Based Training, 1. and 3. Semester

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>365-1099-00L</td>
<td>Design Thinking: A Human-Centred Approach to Problem Solving Exclusively for MAS MTEC students (3rd semester). Minimum number of participants: 15 students.</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>L. Armbruster</td>
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</table>

Abstract
In this course, students get to know Design Thinking, which is an innovation method that can be applied to solve a broad range of problems from product development to social innovation. The students will engage in collaborative team exercises to learn about and directly apply the five typical design thinking steps – empathize, define, ideate, prototype and test – by solving a real-world challenge.

Objective
During the course, students will:

- get to know the design thinking process working on a specific real-world challenge
- learn when to apply design thinking methodology
- learn how to empathize with users, how to formulate a clear problem statement, develop ideas, prototype as well as test them with potential users
Participants are introduced to practical frameworks for negations and advocacy and apply them in discussions, cases and exercises.

Based on four Human Resource Management core processes (recruiting, performance management, compensation, training and development), this seminar teaches practical skills in HRM and leadership in teams. Using a variety of interactive methods and discussions of real-life situations, it provides a highly practice-oriented approach to dealing with potential HRM- and team-related conflicts at work.

Objectives

- Students will be able to assess whether Design Thinking is useful methodology to solve challenges they face in their daily business activities.

What the students should learn from the course:

- Students will be able to use elements (i.e. a novel brainstorming technique, a novel feedback method, etc.) in their daily business activities.

What the students will NOT learn:

- This 2-day training is by not extensive enough to provide a full-scale design thinking training that enables students to design, organize and run their own design thinking workshops and projects. For this, further courses, trainings and self-guided learning is necessary.

Exclusively for MAS MTEC students (3rd semester).

The seminar will be a mixture of theory inputs, discussions, self-reflecting moments, group work with short presentations as well as some interactive methods (e.g. role plays) and discussions of real-life situations, it provides a highly practice-oriented, yet theoretically grounded approach to dealing with potential HRM- and team-related conflicts at work.

Topics covered in the seminar include (but are not limited to) questions around hiring new staff, employee motivation (or a lack thereof), measuring performance, fair and effective compensation, pros and cons of monetary incentives, opportunities and limitations of career development in organizations. Furthermore, participants will learn and practically apply techniques that help them to deal with team-related conflicts. Thereby, they gain a better understanding of how and why conflicts in teams may arise and how they can be solved.

The success of this seminar depends greatly on active student participation. Sharing real-life examples from participants' various organizational and professional backgrounds provides the material for engaged and insightful discussions in class as well as in small groups. Also, in order to maximize the learning effect of this seminar, participants will be asked to complete a variety of short assignments prior to and between the three modules. The assignments will help them to prepare for the modules and reflect on the various themes in more depth. Based on the assignments, the discussions during the seminar will be much more focused and effective.

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In this course participants are introduced to the practical dimensions of how organization's represent their interests vis-à-vis external stakeholders.

Participants will learn basic frameworks and theories for
- stakeholder mapping and management
- advocacy campaign design
- negotiations preparation and execution

and apply them to practical contexts through discussions, group exercises and simulations.

This two-day skills course gives students a basic introduction to how organizations represent their interests vis-à-vis external stakeholders. In particular, it examines negotiations (exchanges between parties designed to reconcile their differences and produce a settlement) and advocacy ( imparting or exchanging information through speaking, writing or some other medium with the aim of influencing another party).

The course comprises a mixture of lectures, discussions, group work and simulations. It complements the material covered in Introduction to Negotiation, a required pre-requisite to this course.

The first day focuses on negotiations skills and covers the following topics:
- Planning and preparation for negotiations
- Common frameworks for negotiations
- Social dimensions (power, influence, persuasion, behavior cues, culture, and gender) of negotiations
- Ethics and ethical dilemmas in negotiations and advocacy

The main group exercise of the first day is a negotiation simulation.

The second day focuses on advocacy and covers the following topics:
- Lobbying and policy foundations
- Stakeholder mapping and management
- Advocacy campaign design
- Message and presentation design

The main group exercise of the second day is a case study discussion and presentation.

The course is structured to give an introductory overview of the topics. Recommended readings for further studies will be provided on moodle. Students will be required to read the instructions for the negotiation simulation and the case study before arriving in class.

Attendance and participation is required on both course days.

Pre-Work: you will be expected to distribute a survey to 5-6 members of your trusted network (e.g. friends, family and work colleagues). The surveys are private and only you will see the information. The survey will be the basis of defining your current personal brand.

Additional pre-work will be reading through some articles and completing the first section of your Personal Journal.

Specific take-aways from this course:
- Your personal brand
- Your desired personal "brand house"
- Storytelling frameworks
- Building of your personal story and practice giving them
- Elevator Pitches and practice giving them
- Review of online & offline communication channels with an action plan to activate
- Your Personal Journal to keep and reflect on throughout your career.

The Personal Branding and Storytelling course will be divided into the following sessions:

**Pre-Work:** you will be expected to distribute a survey to 5-6 members of your trusted network (e.g. friends, family and work colleagues). The surveys are private and only you will see the information. The survey will be the basis of defining your current personal brand.

Additional pre-work will be reading through some articles and completing the first section of your Personal Journal.

**Brand Basics:** gain a common understanding of what a brand really is and why it is important. We will explore the difference between a corporate brand and a personal brand.

**Brand Building:** using the pre-work material, we will look at your current personal brand vs. your desired brand. We will take an in-depth look at all parts of a brand house and help you define your own Unique Selling Points (USPs). We will have exercises and break into small teams as needed.

**Storytelling Basics:** gain a common understanding of the importance of storytelling and different frameworks to approach it.

**Storytelling Practice:** you will spend time developing your personal story and Elevator Pitch. We will have exercises and break into small teams as needed. You will be given the opportunity to tell your story and obtain feedback.

**Communication Channels:** we will review the various online and offline communications channels open to you to build your brand with a strong focus on LinkedIn. You will develop a personal action plan based on the channels most relevant to your industry and profession.

Attendance at both days of the course and active participation in the exercises in mandatory for successful completion of the course.

Students will be expected to fully complete the pre-work required, including gathering the Trusted Network Survey data and filling in the first part of the Personal Journal. Literature and readings will be announced beforehand.

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### Electives, 1. and 3. Semester

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<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>365-1145-00L</td>
<td>Applied Finance and Investment for Managers</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>S. Zaker</td>
</tr>
</tbody>
</table>

Exclusively for MAS MTEC students (3rd semester).
Abstract

The focus is on how financial and investment theory is applied to real world problems. We compete in the economy, but are also exposed to financial markets. The specific point of view, the language of financial markets are discussed using illustrative case studies. Managers will learn how their company is rated for debt financing; and how its value reflects in the “mirror” of private equity funds.

Objective

1) Understanding the mechanisms, language, and drivers of the debt and equities markets

2) Apply this understanding to specific corporate situations, such as optimizing the cost of capital (debt and equity) of the firm or projects

Content

Part 1: A Practical Introduction to the Financial Markets

Your Company’s profile in the mirror of financial markets. How would experts analyze your company, its strengths, and weaknesses?

The financial market eco-system. Understanding the cogs and wheels of financial markets, and the existing checks and balances.

Key actors in the financial markets. How central banks, commercial banks, and institutional investor influence market trends.

1. How digital transformation affects businesses (insights across industries), processes and organizations
2. That this is not only a technology but a human change as well
3. How today’s governance and organization need to be adopted to these trends
4. How current Cybersecurity approaches look like integrating the cloud

Part 2: Case Studies

Case study 1. How does your pension fund work?
Case study 2. When Activist Hedge Funds approach a company.
Case study 3. Merger and Acquisitions.
Case Study 4. A Financial Market View of your Firm

365-1143-00L Digital Transformation: Integrating Cloud and Business

Exclusively for MAS MTEC students (3rd semester).

Abstract

Digitalization changes our life and how companies do business. As a consequence, the role of IT and Cybersecurity changes, and these changes create new and unknown disruptive challenges for organizations. Based on practical experience we will look into some of these areas like Cybersecurity, governance, organization etc. always with a risk management focus.

Objective

1. How digital transformation affects businesses (insights across industries), processes and organizations
2. That this is not only a technology but a human change as well
3. How today’s governance and organization need to be adopted to these trends
4. How current Cybersecurity approaches look like integrating the cloud

Content

The role of IT and Cybersecurity changed dramatically over time. The movement to the Cloud and the digital transformation as such is in the process of shaping a new world, cybersecurity (and privacy) being at the core of it. Digital transformation as well as security arrived now at the board level.

This drives a lot of changes in a lot of different areas: The role of internal IT has to be re-defined; governance processes have to be changed; even the impact on finance and budgeting is not to be underestimated. This course focuses on these challenges and how they can be approached (and have been approached) in the industry. It will base on practical experience with companies across Europe and in different industries.

Besides touching on the basics of Cybersecurity it gives a broader view on the challenges in today’s architectural and governance frameworks and how you can approach these challenges on the technological as well as on the human side. We will jointly work on how the Cloud influences these developments and what changes are necessary to capture the opportunities while maintaining an acceptable risk level.

We want to approach this in an interactive format, while adding background information over the course of the first day (e.g. an introduction to Cybersecurity). Between the first full day and the day 2 (half-day) you work on a case study to be presented and discussed on day 2. On the final slot we will wrap up and fill the blanks and address the questions which remained open.

365-1083-00L Leading the Technology-Driven Enterprise

Exclusively for MAS MTEC students (1st and 3rd semester). Priority will be given to the 3rd semester students.

Abstract

The bloc-course is about change leadership. It provides MAS students with coaching and mentoring from two senior change leaders in the attempt to develop critical management skills and bridge the gap between theory and practice.

Objective

The general objective of the course is to enable MAS students with post work experience to think critically about concepts discussed in class during the course on Introduction to Management (i.e., the transformation process by Nadler and Tushman, 1980) and their own professional challenges.
The course has two goals. First, participants learn to decompose complex real life problems into underlying strategic issues. Second, 

This lecture is a special course for MAS students which supplements the Strategic Management course. Participants work on real-life strategy problems in a two-day workshop and apply concepts & methods from the Strategic Management course to develop suitable solutions.

The course has two goals. First, participants learn to decompose complex real life problems into underlying strategic issues. Second, students learn to transfer and use the concepts and methods from the Strategic Management lecture to develop solutions for the identified strategic issues in real-life business contexts.

Content
First workshop day:
Participants revisit core concepts and methods from the Strategic Management lecture. Moreover, participants learn the conceptual steps of defining strategic questions and developing suitable solutions for real-life settings. This conceptual process is then illustrated with an in-depth case study of a strategy consulting project that one of the lecturers conducted. The second part of the workshop day is the starting point for the group work phase. Participants identify a strategic problem that they face at work and team up (each group consists of 4-6 participants) to develop solutions by applying the concepts and methods from the Practicing Strategy class. At the end of the first workshop day, each group has defined one strategic question and developed a rough course of action for developing solutions until the second workshop day.

Between workshop days:
Participants work in small groups to develop solutions for the strategic problem that they identified on the first workshop day. This phase requires participants to select concepts and methods that are suitable to approach the strategic question. Moreover, students collect and analyze data. Subsequently, participants draw upon their analysis to develop solutions to the strategic problem. In this phase, participants can rely on the support and feedback from the teaching team.

Second workshop day:
Participants present their group work followed by an in-depth discussion and feedback session for each group project. Successful registration and participation (either parallel enrolment or successful completion in a previous semester) in the course "Strategic Management" is required (see Course Catalogue page for details).

Prerequisites / notice
Exclusively for MAS MTEC students (3rd semester).
A prior/parallel enrolment for the lecture "Strategic Management" (363-0392-00) is mandatory.

Understanding Human Behavior - Research and Business Insights 

Abstract
Human capital is the most precious resource of every company, while customers are the backbone of a company’s functioning. This course demonstrates the application of behavioral science theories to improve decision making within the company and to better understand its customers. In this course, psychology meets finance, data science and analytics to address practical business problems.

Objective
The course objective is to provide a crash-course of behavioral economics and decision science with a special focus on aspects particularly important in business and international companies. The aim of the course will be to apply theoretical knowledge obtained during the classes at ETH in practical business cases stemming from ETH industry partners.

Content
This block course is divided into three sessions:
1. Theory Part: Students get familiar with the Nobel-Prize winning theories, key concepts, models and findings in decision science and behavioral economics. The covered topics include judgment and decision making, heuristics, biases and heuristics, nudges, psychometrics, risk appetite elicitation, digital and physiological footprints of decisions, and impact of emotions and environment on decisions. The material will be aligned with relevant real-life examples that relate to important societal and business problems. The students will be introduced to the behavioral study design, behavioral analytics and research methods that can be applied in a business environment accounting for its advantages and limitations.
2. Business Insights Part: In this part students learn how the behavioral aspects enter into business processes, workflows and customer relations. An industry partner (Swiss Re) will present a business case related to behavioral science. Students challenge these cases in groups based on the theoretical part and guidance from lecturers. Students will form groups to solve the business case, using the knowledge acquired during the theoretical part of the course and relevant course material.
3: Final Presentation Part: This session will take place at the industry partner's venue, where the students will present their business case solutions.

Attendance during the meetings and solving the business case are mandatory requirements for successful completion of the course. Course material includes the lecture slides and scientific papers.

Unethical Decision Making: Alternative and Critical Thinking in Management

Abstract
This course is about decision making processes in complex situations involving financial, relational and ethical problems. First, it provides fundamental tools for addressing problematic situations. Second, it discusses how stakeholders' ethical expectations and social responsibility issues can be effectively implemented and integrated in organizational systems and strategic planning processes.
In this seminar students can expect to:

- Become familiar with tools and procedures to prevent, identify and resolve corporate fraud and crime in organizations
- Understanding the mutual relationship between financial, relational and ethical drivers in managerial decision making
- Become familiar with tools and procedures to prevent and resolve corporate crises and scandals
- Understanding the opportunities associated with the corporate social responsibility (CSR) movement and how to integrate CSR in organizational and strategic planning
- Create an effective CSR strategic planning process to successfully develop and implement a CSR package
- Understand a variety of strategic CSR planning tools
- Become familiar with creating deep destructive change in pursuit of dual economic and social value

Content

Why incredibly intelligent people do incredibly stupid things? What are the most frequent dynamics associated with corporate fraud and corruption? What should be done to avoid mobbing or discrimination in organizations? And how organizational crises can be prevented and eventually resolved? What is cosmetic corporate social responsibility?

On a more positive tone, how companies could create a culture that fosters personal and professional development? How do companies contribute to the development of societies where they operate? How do they contribute to alleviate the global problems and to promote a sustainable development?

This course will address these questions through case discussions, lectures and the presentations of invited speakers.

The main objective is to develop multiple, alternative, provocative, critical but constructive, perspectives of main ethical issues affecting the management of organizations today. We will “think out of the box”, learn how to look using the different perspectives of multiple stakeholders, take the defense of forgotten people, look at corporate power as an opportunity for organizational and social welfare… said in other terms, this is a course to think alternatively and creatively!

Lecture notes

Classes are taught through a series of cases that represent real management decisions. Students are required to prepare all of the assigned cases carefully before each class, to participate actively, and to respond thoughtfully to classmate comments.

Students will also work in teams to analyse and address ethical dilemmas, and strategic decisions involving ethical, environmental or societal issues.

Literature

This course is based on mini-cases.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Type</th>
<th>Credits</th>
<th>Module</th>
<th>Professor</th>
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</thead>
<tbody>
<tr>
<td>363-1044-00L</td>
<td>Applied Negotiation Seminar</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>A. Knobel</td>
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<td></td>
<td>Prerequisites: Successful completion of lectures &quot;363-1039-00L Introduction to Negotiation&quot;.</td>
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<td></td>
<td>Abstract</td>
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<td></td>
<td>The block-seminar combines lectures introducing negotiation and negotiation engineering with the respective application through in-class negotiation case studies and games.</td>
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<td>Objective</td>
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<td>In this seminar students can expect to:</td>
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<td>- learn more theory of negotiation and apply this learning in simulated negotiations</td>
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<td></td>
<td>- have their perceptions of rationality, fairness and trust challenged through little embedded experiments</td>
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<td>- learn to recognize and analyze negotiation contexts and interests and generate creative solutions</td>
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<td>- learn to negotiate under pressure (with time and mandate restrictions) and experience (and potentially chair) a formal negotiation</td>
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<td>- learn to read, analyze and present a scholarly paper</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>This block seminar is an extension of the course &quot;Introduction to Negotiation&quot; and provides more detailed insight into key aspects of the field of negotiation and negotiation engineering.</td>
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<td>In particular,</td>
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<td>- a series of brief lectures will outline foundational aspects of negotiation science, such as rationality, fairness, and trust, as well as the possible application of machine learning in negotiation</td>
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<td>- three practitioners will describe lessons learnt in their negotiation domains (diplomacy, labor, and business) and allow time for Q&amp;A and discussion</td>
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<td>- Professor Ambühl will elucidate further current cases from his professional experience</td>
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<td>- students will apply course input in a number of challenging simulations (ranging from simple 30 minute games to full-fledged international ten party negotiations). In each game they will be asked to represent a party and negotiate as skillfully as they possibly can within the constraints of their mandate</td>
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<td>- each student will be assigned a scholarly paper (20 to 30 pages) between the two blocks to read. They will give a 20 minute group presentation with one or two of their peers and submit a brief reflection report after the seminar</td>
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<td></td>
<td>The course size is deliberately limited (30 maximum) to enable ample opportunity to interact with the lecturers, guests and each other.</td>
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<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Type</th>
<th>Credits</th>
<th>Module</th>
<th>Professor</th>
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</thead>
<tbody>
<tr>
<td>363-0861-00L</td>
<td>Alliance Advantage - Exploring the Value Creation Potential of Collaborations</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>C. G. C. Marx</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The development of new business models coping with the constantly augmenting complexity of technologies and systems as well as the ever increasing global competition force organizations to focus on close collaboration with key partners. These alliances are key value creation opportunities and constitute the core part of this lecture.</td>
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<td>Objective</td>
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<td></td>
<td>Learning outcomes professional competence</td>
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<td></td>
<td>- The students learn and understand the management basics of inter-firm cooperation and organizational networks (business models, incl. risk, communication, etc.)</td>
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<td>- realize the value creation potentials of alliances (added value)</td>
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<td>- understand underlying theoretical models (Transaction cost theory, principal agent, game theory)</td>
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<td>- identify and understand specific forms of collaboration (Strat. All., JV, Networks, M&amp;A, etc.)</td>
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<td>- apply tools hands on in real companies (in coll. with companies)</td>
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<td>Learning outcomes methodological competence</td>
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<td></td>
<td>- Writing academic papers</td>
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<td>- Developing structured documentation of interviews</td>
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<td></td>
<td>- Transferring theory directly into application</td>
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<td></td>
<td>- Contributing to the learning journey</td>
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<td>Learning outcomes social competence</td>
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<td></td>
<td>- Work together with industrial partners</td>
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<td>- Improving communication skills as basics for collaboration</td>
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<td></td>
<td>- Developing and applying team work skills</td>
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<td>- Coping with conflicts resolution in teams</td>
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</table>
The constantly augmenting complexity of technologies and systems, the increased pressure caused by competition, the need for shortening time-to-market and the thereby implied growing risks force organizations to increasingly focus on core competencies. Collaboration with external partners is a key value creation opportunity for successful ventures. This type of cooperation also has implications on daily management activities. This lecture will provide a better understanding of special requirements needed for management of cooperation issues.

Content:
- Introduction to theory and management of inter-firm collaboration and networks.
- Description of the formation, management and evolution of collaborations and networks.
- Collaborations in marketing, development, manufacturing (e.g. NUMMI).
- Special forms of collaborations: mergers & acquisition (e.g. pre- and post-merger activities, joint venture, strategic alliances (e.g. Doz & Hamel, networks, virtual communities)

Learning journey:
In an introductory lecture we will give an overview of the theoretical framework and explain the concept of the lecture (first week of semester, Sept. 19, 2019). In weeks 2-5 you will work on a first assignment on six different aspects of the underlying framework: strategy and activities, structure and process, culture and people orientation, interaction and roles, risk and trust, knowledge and learning. This first assignment will give you the basics to participate in the second part (Nov. 7+8, 2019) of this seminar. There you will present the results of the first assignment and get additional theoretical input to perform the 2nd assignment. The second assignment will be to analyze real alliance projects in the partner companies. The final lesson will be used as a best practice exchange (Dec. 19, 2019).

Objective
1. Understanding and applying common business tools and frameworks
2. Understanding current challenges of managers in technology intensive markets
3. Defining and analyzing comprehensive business problems using the example of a leading Swiss manufacturing company (Bühler AG)
4. Developing and evaluating different alternative case solutions
5. Making decisions on case solutions, justifying and defending them
6. Transferring case solutions into practice by formulating specific instructions for the management
7. Creation of novel, innovative ideas that help the company to gain a competitive edge
8. Cooperation in teams and coordination of team tasks
9. Adequate communication to and eye-level discussions with C-level managers

Abstract
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology intensive markets by using real life cases.

Content
The seminar “Cases in Technology Marketing” introduces students to key concepts and tools in technology marketing and familiarizes them subsequently with the challenges that (marketing) managers face in technology intensive markets by using real life cases. Students will have to work in groups and together solve past, current and future managerial problems in the form of cases. The team member composition will rotate for each case, enabling students to foster their teamwork abilities besides the application of theoretical concepts to the applied case questions. The students will have to present their case solutions to the lecturer and a top executive of a leading Swiss company (details see below). Also, they will be enabled to compare their solutions with what has actually been done or is yet to be done.

The three case studies presented in this course cover real managerial issues of the Swiss manufacturer Bühler AG (www.buhlergroup.com). A Bühler top executive will present the cases and discuss the students' presentations and solutions. As such, the course allows for in-depth discussions of the real-life case solution with the C-level manager and hereby enables students to transfer their learnings from theoretical considerations to the applied field. The course will be rounded off with a day-visit to the Bühler facilities in Uzwil, Switzerland, where students will have the chance to further connect with management and discuss the acquired key concepts, tools, and case study insights on site.

Prerequisites / notice
In addition to course enrolment, students have to apply for this course by sending a CV and a short motivation letter until 20.08.2021 to Theresa Schachner: tschachner@ethz.ch.

363-0393-00L Corporate Strategy
Due to didactic considerations, the number of participants for this course is limited to 45.

Abstract
This course focuses on the challenges in managing multi-business corporations, and covers topics related to the vertical and horizontal scope of business activities.

Objective
The course is a combination of lectures about concepts/methods, guest lectures, case studies, and individual assignments.
Large- and medium-sized corporations play a central role in the economic activity of most developed and developing countries. Many of these organizations perform multiple business activities in multiple markets. In the face of increasing international competition, globalization, technological development, deregulation, and the emergence of new markets and industries, operating such a portfolio of business activities poses important managerial challenges forcing corporations to continuously re-consider their vertical and horizontal scope and boundaries.

The course Corporate Strategy draws from a wide range of theories and methods to develop an understanding of the conceptual frameworks, debates, and developments concerning decisions associated with the management of multi-business corporations. We will cover the key questions driving a firm's corporate strategy, including:

- In what markets to compete with which businesses?
- Which activities should be performed by the firm and which should be outsourced (i.e. "make" or "buy" decisions)?
- What are the most appropriate approaches to growth and divestiture?
- How do institutional forces impact corporate strategy?

Specifically, we will examine how organizations manage their portfolio of business activities and markets to achieve competitive advantage through vertical integration, cooperative strategies such as strategic alliances and joint ventures, corporate diversification, mergers and acquisitions, divestitures, and globalization/international strategies, and strategic renewal.

Prerequisites / notice

The course homepage can be found at: http://www.smi.ethz.ch/education/corporate-strategy.html

Having participated in the course Strategic Management by Prof. Georg von Krogh/Dr. Stephan Herting is an advantage but not a requirement.

Taught competencies

- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Problem-solving
  - Critical Thinking
  - Self-direction and Self-management
  - Taught
  - assessed

363-1135-00L Digital Health Project

Number of participants limited to 30.

Abstract

Today, we face the challenge of dealing with the specific characteristics of chronic conditions. These are now responsible for around 70% of all deaths worldwide and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. Chronic conditions require an intervention paradigm that focuses on prevention and lifestyle change. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socio-cultural influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

Against this background, the question arises on how to develop evidence-based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, information systems research, computer science, and behavioral medicine, this course has the objective to help students and upcoming healthcare executives interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs. After the course, students will be able to:

1. understand the importance of DHIs for the management of chronic conditions
2. discuss the opportunities and challenges related to DHIs
3. better understand the design, implementation, and evaluation of smartphone-based and chatbot-delivered DHIs

Objective

The increasing prevalence of chronic conditions leads to the important question of how to develop evidence-based digital health interventions (DHIs) that allow medical doctors and other caregivers to scale and tailor long-term treatments to individuals in need at sustainable costs. At the intersection of health economics, information systems research, computer science, and behavioral medicine, this course has the objective to help students and upcoming healthcare executives interested in the multi-disciplinary field of digital health to better understand the need, design, implementation, and assessment of DHIs. After the course, students will be able to:

1. understand the importance of DHIs for the management of chronic conditions
2. discuss the opportunities and challenges related to DHIs
3. better understand the design, implementation, and evaluation of smartphone-based and chatbot-delivered DHIs

Content

Today, we face the challenge of dealing with the specific characteristics of chronic conditions. These are now responsible for around 70% of all deaths worldwide and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. Chronic conditions require an intervention paradigm that focuses on prevention and lifestyle change. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socio-cultural influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

Today, we face the challenge of dealing with the specific characteristics of chronic conditions. These are now responsible for around 70% of all deaths worldwide and are associated with an estimated economic loss of $7 trillion between 2011 and 2025. Chronic conditions require an intervention paradigm that focuses on prevention and lifestyle change. A corresponding change in lifestyle is, however, only implemented by a fraction of those affected, partly because of missing or inadequate interventions or health literacy, partly due to socio-cultural influences. Individual personal coaching of these individuals is neither scalable nor financially sustainable.

To reach the learning objectives, students will work on the following topics:

1. Motivation for Digital Health
   • The rise of chronic diseases in developed countries
   • Lifestyle as medicine and prevention of chronic diseases
2. Design of a Digital Health Intervention (DHI)
   • Overview of design frameworks for health interventions
   • Development of a conceptual model for a DHI
   • Implementation of a smartphone-based and chatbot-delivered DHI
3. Evaluation of DHIs
   • Overview of evaluation methods and criteria for DHIs
   • Evaluation of a smartphone-based and chatbot-delivered DHI

Course structure

The lecture is structured in two parts and follows the concept of a blended treatment consisting of online-based self-learning sessions and complementary "support" sessions via Zoom. In the first part, students will learn about the topics of the three learning modules in weekly online sessions. Complementary learning material (e.g., video clips), multiple-choice exercises are provided online via Moodle. In the second part, students work in teams and will use their knowledge from the first part to develop a smartphone-based and chatbot-delivered health intervention with MobileCoach (www.mobile-coach.eu), an open-source software platform for digital interventions and ecological momentary assessments. Each team will then present and discuss their resulting digital health intervention and evaluation results with their fellow students who provide peer-reviews. Additional online coaching sessions are offered to support the teams with the design and evaluation of their digital health intervention, and with the preparation of their presentations.
Literature


Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td>Project Management</td>
<td>assessed</td>
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<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
<td>Negotiation</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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363-1082-00L Enabling Entrepreneurship: From Science to Startup

W 3 credits 2V A. Sethi

Abstract

This elective is relevant for students who have developed a technology and are keen to evaluate the steps in starting a startup. This is also relevant for students who would like to start a startup but do not have a technology, but are clear on a specific market and the impact they would like to create.

Objective

Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs
2. The students can be from business or science & technology
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.
The students would cover the following topics, as they build their idea into a business case:

1. Technology excellence: This assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market.
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identifying how relevant the market perceives the technology, and whether this can sustain over a longer period of time.
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers.
4. Team including future capabilities required: A startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup.
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company.
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It’s important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders.
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay.
8. Legal overview, company forms and shareholders’ agreements (including pitfalls): The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Lecture notes
Since the course will revolve around the ideas of the students, the notes will be for the sole purpose of providing guidance to the students to help convert their technologies or ideas into business cases for the purpose of forming startups. Theoretical subject matter will be kept to a minimum and is not the focus of the course.

Lecture notes
The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

Literature
Book
Sethi, A. “From Science to Startup”
ISBN 978-3-319-30422-9

Prerequisites / notice
This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

Limited number of participants.
Students apply for this course via the official website no later than August 23.
Once your application is confirmed, registration in myStudies is possible.

Abstract
This seminar provides master and PhD students at MTEC with the challenging opportunity of a real case on strategy, innovation and leadership in close collaboration with the top management of a leading Swiss manufacturing company: Georg Fischer.

Objective
The general objective of the course is to enable MTEC students to develop leadership skills by dealing with real-world business problems, thinking critically about the concepts discussed in their study programs and learning how to apply these concepts to provide practical implications. It provides students with coaching and mentoring from senior leaders in the company and professors from D-MTEC to bridge the gap between theory and practice.
This seminar provides ambitious ETH students and doctoral candidates with a rewarding learning opportunity: a real case study of strategy and innovation in close collaboration with the top management of an outstanding company: Georg Fischer.

What you can expect:

You will work in teams on specific high-priority assignments that flow from the company. Delving into the assignments you will both contribute to solving strategic issues and have an impact on their implementation at the company.

To gain insight into the company and its culture you will receive briefings from senior management, conduct interviews with experts and run workshops with your case managers. In the final presentations you will pitch your findings to key stakeholders and top management representatives and receive valuable feedback. Furthermore, you will be coached and supported by MTEC professors on the topics of project scoping, problem definition and solving, process improvement, strategy and board presentation.

The course is directed and organised by PD Dr. Zeynep Erden and Dr. Isabel Spicker as part of the MTEC Leadership Development Programme.

What we expect from you:

You are an ambitious ETH student or doctoral candidate who is looking for a rewarding learning opportunity and is eager to go the extra mile. You will work on a real case study of strategy, technology and innovation in close collaboration with the senior management of an outstanding Swiss company. The recommendations that you formulate in collaboration with members of your team as well as with internal and external experts will be discussed at the Partner and Director levels. This demands a deep understanding of the company’s leadership culture.

In this endeavour you are coached and supported by

- Stefano Brusoni, Chair of Technology and Innovation Management
- Georg von Krogh, Chair of Strategic Management and Innovation
- Torbjörn Netland, Chair of Production and Operations Management
- Zeynep Erden, Vlerick Business School / D-MTEC

Literature and readings will be announced in the coaching sessions.

Please apply for this course via the official website (www.mtec.ethz.ch). Apply no later than August 22.

The number of participants is limited to 18.

ECTS: 4

Participants receive a certificate.

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course title</th>
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</thead>
<tbody>
<tr>
<td>363-0887-00L</td>
<td>Management Research</td>
</tr>
</tbody>
</table>

**Abstract**

Students learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop their own research projects.

**Objective**

You will learn how to approach management research from various perspectives, how to evaluate empirical research, and how to develop your own research project. The successful completion of the course will help you to:

- Think critically and make compelling arguments about the strengths and weaknesses of published management research
- Find and review appropriate literature and previous research for your thesis
- Develop and frame interesting and relevant research questions and problem statements
- Design your research and choose an appropriate methodology for analysis (specific research methods and techniques are not discussed in this course)
- Structure your manuscript
- Plan and manage your thesis project

**Content**

This course combines lectures, group discussions and individual assignments.

Day 1: Course introduction, group analysis exercises and discussions, lectures on main topics. Between course days 1 and 2: Individual and group work on assignments.

Day 2: Assignment review and discussion, lectures on main topics, conclusion session.

**Target audience:**

The course is designed with two groups of students in mind: first, students who write their master thesis at the SMI chair and second, students who write their master thesis in the field of management at other MTEC chairs. For both groups, the focal topics of this course will arise frequently during the journey of writing their thesis, and the majority of topics are relevant for all students. However, we will provide some specific content (grading guidelines, thesis format) which might not be applicable for students tutored at other MTEC chairs.

**Course topics:**

1. Thesis topic and thesis proposal:
   - Choice of thesis topic, identification of research gap, formulation of research questions, writing of thesis proposal
2. Literature review:
   - Search and evaluation of academic literature, use of reference tools, writing of theoretical background chapter of thesis
3. Empirical research design:
   - Types of empirical research designs, choice of methodology, overview of data collection and analysis methods
4. Research output and report:
   - Writing of introduction, results and conclusion, thesis format and structure
5. Thesis assessment:
   - SMI grading criteria, MTEC guidelines

**References:**


This course is for all students who write their master thesis at the Department of Management, Technology, and Economics.

The course is required for all M.Sc. students and MAS students who write their master thesis at the Chair of Strategic Management and Innovation.

The course is graded based on the assignments, peer feedback, and participation in group discussions.

The first assignment is due before the first course day. Please check the assignments on the Moodle coursepage. If you sign up for the course on short notice before the first course day, please advise the lecturer of your registration by email.

### 363-1080-00L  
**Power and Leadership**  
**W**  
**3 credits**  
**2S**  
**P. Schmid**

**Abstract**  
Students will learn about different leadership styles and how power and leadership play out in social interactions. Emphasis is placed on personal development and the implementation and application of topics to the workplace context.

**Objective**  
This course will enhance students’ understanding of the complexity of hierarchical relationships in the workplace in weekly lessons that include lectures, analyses of leadership situations (e.g., case studies), exercises, and group discussions. More specifically, students will be informed about how power shapes people’s behaviors and decision-making processes. They will learn to analyze the different elements that make a good leader such as personality traits, behavior, and skills. With case studies and small group exercises, students will learn to evaluate different types of social and emotional skills related to leadership. Students will be encouraged to reflect upon their own communication skills and leadership potential and will be given the opportunity to train their leadership skills. The course further addresses integrity and ethics in leadership.

**Content**  
Lectures will include:
- Introduction to the course and the topic of power and leadership, definitions
- Leadership styles and theories: Universalist theories, behavioral theories, contingency theories, “new leadership” theories
- Leadership, communication, and interpersonal skills (3 sessions): 1. Effective communication: Listening and speaking, running effective meetings, delegating effectively, giving performance feedback, 2. Hierarchy and communications: Pitfalls and solutions, communication training, 3. Importance of social skills for leadership effectiveness
- Agility in teams: Overview of the Scrum Framework in the context of software development, leadership in agile teams, the role of motivation, training: experiencing first-hand how to develop a product in an agile way
- Power abuses, ethics in leadership: Why do leaders behave unethically? Destructive leadership: theories, examples, and consequences
- Diversity and discrimination in relation to power and leadership: Expectations, bias, and discrimination the workplace, sources of bias, how to reduce bias and discrimination
- Leadership and innovation: Which are the particular paradoxes and trade-offs leaders face when they are leading for innovation? How could they successfully manage those challenges?

**Homework**
- Analysis of Visionary Speeches (~10 hours)
- Preparation of a video of a 2-min speech (incl. training, ~12 hours)
- Providing feedback to two of your classmates on their leadership skills (~6 hours)
- Writing a leadership skills training report (~30 hours)
- Mandatory and facultative readings and exercises (~10 hours)

**Literature**  
Mandatory readings:


**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories  
- Domain B - Method-specific Competencies: Analytical Competencies  
- Domain C - Social Competencies: Communication  
- Domain D - Personal Competencies: Adaptability and Flexibility

**363-0445-02L  
Production and Operations Management – Supplement Credit**

**W**  
**1 credit**  
**1A**  
**T. Netland**

**Abstract**  
This course is an extension to the course 363-0445-00 Production and Operations Management. Participants get an extra deep dive into key concepts of POM.

**Objective**  
This course strengthens the learning objectives of the POM core course (see separate syllabus). After completing this course,
- students can use lean thinking to improve the productivity of production processes,
- students can conduct fundamental process mapping analyses,
- students can select and implement many lean production techniques,
- students can select and use problem-solving tools and methods, and
- students understand the role of management in manufacturing.

**Content**  
This course is an extension to the course 363-0445-00 Production and Operations Management. Participants get an extra deep dive into key concepts of POM.

The lectures in this course are highly interactive. To pass this course, students need to complete a course assignment in pairs. The course assignment consists of two parts: preparations for the lecture and a reflection essay after the lecture.
In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the
Technology Entrepreneurship
See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html
Psychological Aspects of Risk Management and
F. Hacklin

The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations.

- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about (and partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

- Group projects related to company case studies

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

363-0311-00L Psychological Aspects of Risk Management and Technology
W 3 credits 2V G. Grote, N. Bienefeld-Seall, J. Schmutz, R. Schneider, M. Zumbühl
Number of participants limited to 65.
Abstract
Using uncertainty management by organizations and individuals as conceptual framework, risk management and risk implications of new technologies are treated. Three components of risk management (risk identification/evaluation, risk mitigation, risk communication) and underlying psychological and organizational processes are discussed, using company case studies to promote in-depth understanding.
Objective
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about (and partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

- Group projects related to company case studies

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

363-0790-00L Technology Entrepreneurship
W 2 credits 2V F. Hacklin
Number of participants limited to 53.
Abstract
Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding. This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are entrepreneurial understanding.
Objective
- You know how risk and risk management is defined and applied in different industries
- You know the challenges of decision making under risk and uncertainty and its effects on organisations
- Know about (and partially) apply some risk management tools
- Gain some more in-depth knowledge in a selected field within risk management through the semester project (e.g. transport systems, IT, insurance)

This course consists of three main elements:

A) Attendance of lectures that provide the theoretical foundations of “Psychological Aspects of Risk Management and Technology” together with reading assignments for each lecture.

B) Attendance of guest lectures that provide a rich source of practical insights and enable the transfer of theory into practice by discussing real-life cases with experts from various industries.

C) Furthermore, this course enables you to apply what you have learned in the classroom into practice by participating in a group assignment in which you gain insights into various risk industries (e.g., aviation, healthcare, insurance) and topics (e.g., risks in cyber-attacks, mountaineering, autonomous vehicles). These projects help students understand key aspects through in-depth application of the course material on real-life topics. Each group project will be mentored and graded by one of the lecturers (70% of course grade). To round off the course at the end of the year, you will have the opportunity to present your group’s findings to the lecturers and to your peers (30% of course grade).

Content
The course is organized into fourteen sessions. Sessions comprise a mixture of (guest) lectures, case discussions, and presentations. Through class discussion we will further deepen understanding of the topics and themes of the class. For each session you are required to prepare by reading the assigned literature or case material provided on the Moodle e-learning platform. Topics covered include:

- Elements of risk management:
  - Risk identification and evaluation
  - Risk mitigation
  - Risk communication

- Psychological and organizational concepts relevant in risk management
  - Decision-making under uncertainty
  - Risk perception
  - Resilient organizational processes for managing uncertainty

- Case studies on different elements of risk management (e.g., rule-making, training, managing project risks, automation)

- Group projects related to company case studies

Lecture notes
There is no script, but slides will be made available before the lectures.

Literature
There are texts for each of the course topics made available before the lectures.

Prerequisites / notice
The course is restricted to 40 participants who will work closely with the lecturers on case studies prepared by the lecturers on topics relevant in their own companies (SWICA, SWISS, University Hospital Zurich).

365-0899-00L Master's Thesis in a Company
Exclusively for MAS MTEC students.
W 12 credits 24D Professors
Number of participants limited to 30.
Abstract
In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and is performed within a private company.
Objective
In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is supervised by the tutor and is performed within a private company.

MAS in Management, Technology, and Economics - Key for Type
O Compulsory
W+ Eligible for credits and recommended
W Eligible for credits

E- Recommended, not eligible for credits
Z Courses outside the curriculum
Dr Suitable for doctorate
### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons

The course deals with simple quantitative and graphical as well as more complex methods of biostatistics. Contents: Descriptive statistics,

- Anatomical and anatomical knowledge of the human body to ensure the correct understanding of basic concepts and to facilitate the

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### Practical Work

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>465-0956-00L</td>
<td>Dosimetry</td>
<td>O</td>
<td>4</td>
<td>6G</td>
<td>M. Pruschy</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<tr>
<td></td>
<td>Only for MAS in Medical Physics</td>
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<td></td>
<td></td>
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<tr>
<td>Abstract</td>
<td>Dosimetry in radiotherapy. Planning and implementation of a percutaneous radiation exposure on an anthropomorphic phantom. Verification of the resulting dose distribution.</td>
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<tr>
<td>Objective</td>
<td>Praktische Umsetzung der Lerninhalte der Vorlesungen Medizinphysik I &amp; II bezüglich Dosimetrie bei perkutanen Strahlenexpositionen</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Dosimetrie in der Strahlentherapie. Planung und Durchführung einer perkutanen Strahlenexposition an einem anthropomorphen Phantom. Überprüfung der resultierenden Dosisverteilungen.</td>
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<tr>
<td>Lecture notes</td>
<td>Die Kursunterlagen werden im Blockkurs abgegeben.</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Voraussetzung: Besuch der Vorlesung Medizinische Physik I</td>
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### Specialisation in General Medical Physics

### Major in Radiation Therapy

### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0341-00L</td>
<td>Medical Physics I</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Manser</td>
</tr>
<tr>
<td></td>
<td>Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.</td>
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<tr>
<td>Objective</td>
<td>Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society.</td>
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<tr>
<td>Content</td>
<td>The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the excercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be provided.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.</td>
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<tr>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0943-00L</td>
<td>Radiobiology</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Pruschy</td>
</tr>
<tr>
<td></td>
<td>The purpose of this course is to impart basic knowledge in radiobiology in order to handle ionizing radiation and to provide a basis for predicting the radiation risk.</td>
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</tr>
<tr>
<td>Objective</td>
<td>By the end of this course the participants will be able to: a) interpret the 5 Rs of radiation oncology in the context of the hallmarks of cancer b) understand factors which underpin the differing radiosensitivities of different tumors c) follow rational strategies for combined treatment modalities of ionizing radiation with targeted agents d) understand differences in the radiation response of normal tissue versus tumor tissue e) understand different treatment responses of the tumor and the normal tissue to differential clinical-related parameters of radiotherapy (dose rate, LET etc.).</td>
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</table>
Practical Work

<table>
<thead>
<tr>
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<th>Title</th>
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<th>ECTS</th>
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<tr>
<td>465-0956-00L</td>
<td>Dosimetry</td>
<td>W</td>
<td>4</td>
<td>6G</td>
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<td></td>
<td>Does not take place this semester. Only for MAS in Medical Physics</td>
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<td></td>
<td>Abstract</td>
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<td></td>
<td>Dosimetry in radiotherapy. Planning and implementation of a percutaneous radiation exposure on an anthropomorphic phantom. Verification of the resulting dose distribution.</td>
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<td>Objective</td>
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<tr>
<td></td>
<td>Praktische Umsetzung der Lerninhalte der Vorlesungen Medizinphysik I &amp; II bezüglich Dosimetrie bei perkutanen Strahlenexpositionen</td>
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<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Dosimetrie in der Strahlentherapie. Planung und Durchführung einer perkutanen Strahlenexposition an einem anthropomorphem Phantom.</td>
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<td>Transparency of the resulting Dosisverteilungen.</td>
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<td>Lecture notes</td>
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<td></td>
<td>Die Kursunterlagen werden im Blockkurs abgegeben.</td>
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<tr>
<td></td>
<td>Prerequisites / notice</td>
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<tr>
<td></td>
<td>Voraussetzung: Besuch der Vorlesung Medizinische Physik I</td>
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Electives

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Welford</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research. In particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<td>Objective</td>
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<td></td>
<td>Synchrontron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, threedimensional imaging at the microm and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.</td>
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<td>Lecture notes</td>
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<td>Available online</td>
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<tr>
<td>227-0941-00L</td>
<td>Physics and Mathematics of Radiotherapy Planning (University of Zurich)</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>University lecturers</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This lecture will provide a detailed introduction to radiotherapy treatment planning. The course considers the physical interactions of radiation in tissue, the mathematical aspects of treatment planning and additional aspects of central importance for radiotherapy planning.</td>
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<td>Objective</td>
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<td></td>
<td>Students shall develop a thorough understanding of the foundations of radiotherapy from a physics and mathematics perspective, focusing on algorithmic components. After completing the course students should be able to implement the main components of a radiotherapy treatment planning system.</td>
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</table>

Literature

Voraussetzung: Besuch der Vorlesung Medizinische Physik I

Literatur: Beilagen mit zusammenfassenden Texten, Tabellen, Bild- und Grafikdarstellungen werden abgegeben.

Literaturliste wird abgegeben.


Basic Clinical Radiobiology, edited by Joiner, van der Kogel, 2018

Mind the enrolment deadlines at UZH:

https://www.uzh.ch/cmsssl/en/studies/application/deadline.html


UZH Module Code: PHY471


Mind the enrolment deadlines at UZH:

https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

For the former number of this course unit is 465-0951-00L.
Radiotherapy is one of the main treatment options against cancer. Today, more than 50% of cancer patients receive radiation as part of their treatment. Modern radiotherapy is a highly technology driven field.

Research and development in medical physics has improved the precision of radiotherapy substantially. Using intensity-modulated radiotherapy (IMRT), radiation can be delivered precisely to tumors while minimizing radiation exposure of healthy organs surrounding the tumor. Thereby, medical physics has provided radiation oncologists with new curative treatment approaches where previously only palliative treatments were possible. This lecture will provide a detailed introduction to radiotherapy treatment planning and will consists of three blocks:

1. The first part of the course considers the physical interactions of radiation in tissue. The physical interactions give rise to dose calculation algorithms, which are used to calculate the absorbed radiation dose based on a CT scan of the patient.

2. The second part considers the mathematical aspects of treatment planning. Mathematical optimization techniques are introduced, which are used in intensity-modulated radiotherapy to determine the external radiation fields that optimally irradiate the tumor while minimizing radiation dose to healthy organs.

3. The third part deals with additional aspects of central importance for radiotherapy planning. This includes biomedical imaging techniques for treatment planning and target delineation as well as image registration algorithms.

The lectures are followed by computational exercises where students implement the main components of a radiotherapy treatment planning systems in two dimensions in Matlab.

<table>
<thead>
<tr>
<th>Lecture notes</th>
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<tbody>
<tr>
<td>Lecture slides and handouts.</td>
<td>Basic programming skills in Matlab (or willingness to learn) are needed for the exercises. Basic knowledge of calculus is needed, approximately corresponding to the 3rd year of a bachelor degree in physics, mathematics, computer science, engineering or comparable discipline.</td>
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<th>ECTS</th>
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<tbody>
<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
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**Content**

Radiotherapy is one of the main treatment options against cancer. Today, more than 50% of cancer patients receive radiation as part of their treatment. Modern radiotherapy is a highly technology driven field.

Research and development in medical physics has improved the precision of radiotherapy substantially. Using intensity-modulated radiotherapy (IMRT), radiation can be delivered precisely to tumors while minimizing radiation exposure of healthy organs surrounding the tumor. Thereby, medical physics has provided radiation oncologists with new curative treatment approaches where previously only palliative treatments were possible. This lecture will provide a detailed introduction to radiotherapy treatment planning and will consists of three blocks:

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<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
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</table>

**Abstract**

Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

**Objective**

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinetic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

**Major in Biomechanics**

**Core Courses**

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<tr>
<th>Number</th>
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<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
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<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
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</tbody>
</table>

**Abstract**

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Objective**

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

**Content**

Lecture notes | Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://ibb.ethz.ch/education/biomedical-engineering.html

### 227-0965-00L Micro and Nano-Tomography of Biological Tissues

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<th>Type</th>
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<tr>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Welford</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

**Content**
Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

### 376-1651-00L Clinical and Movement Biomechanics

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<tr>
<th>Type</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>N. Singh, R. List, P. Schütz</td>
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</tbody>
</table>

**Number of participants limited to 50.**

**Abstract**
Measurement and modeling of the human movement during daily activities and in a clinical environment.

**Objective**
The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

**Content**
This course includes study design, measurement techniques, clinical testing, accessing movement data and anaysis as well as modeling with regards to human movement.

### 376-1985-00L Trauma Biomechanics

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<th>Type</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>K.-U. Schmitt, M. H. Muser</td>
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</tbody>
</table>

**Abstract**
Trauma biomechanics in an interdisciplinary research field investigating the biomechanics of injuries and related subjects such as prevention. The lecture provides an introduction to the basic principles of trauma biomechanics.

**Objective**
Introduction to the basic principles of trauma biomechanics.

**Content**
This lecture serves as an introduction to the field of trauma biomechanics. Emphasis is placed on the interdisciplinary nature of impact biomechanics, which uses the combination of fundamental engineering principles and advanced medical technologies to develop injury prevention measures. Topics include: accident statistics and accident reconstruction, biomechanical response of the human to impact loading, injury mechanisms and injury criteria, test methods (including crash tests), computer simulations, aspects of vehicle safety. Real world examples mainly from automobile safety are used to augment lecture material.

### Practical Work

#### Number 465-0800-00L Practical Work

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<th>Type</th>
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<tr>
<td>O</td>
<td>4</td>
<td></td>
<td>external organisers</td>
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**Abstract**
The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

**Objective**
The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

### Electives
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

Content
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

376-2017-00L Biomechanics of Sports Injuries and Rehabilitation W 3 credits 2V K.-U. Schmitt, J. Goldhahn

Abstract
This lecture introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.

Objective
Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

Content
This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

Lecture notes
Handouts will be made available.

Literature

Prerequisites / notice
A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

>>> Major in Bioimaging

>>> Core Courses

Number        Title                        Type  ECTS  Hours  Lecturers
227-0386-00L  Biomedical Engineering    W  4 credits 3G  J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong

Abstract
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Objective
Introduce students to the fundamental aspects of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

Content

Lecture notes
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://lbb.ethz.ch/education/biomedical-engineering.html

227-0447-00L Image Analysis and Computer Vision W 6 credits 3V+1U  L. Van Gool, E. Konukoglu, F. Yu

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Course material: Script, computer demonstrations, exercises and problem solutions

Prerequisites:

Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.

The course language is English.

Practical Work

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<tbody>
<tr>
<td>465-0800-00L</td>
<td>Practical Work Only for MAS in Medical Physics</td>
<td>O</td>
<td>4 credits</td>
<td>external organisers</td>
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</tr>
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Abstract

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Objective

The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Electives

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<tbody>
<tr>
<td>151-0605-00L</td>
<td>Nanosystems</td>
<td>W</td>
<td>4 credits</td>
<td>4G</td>
<td>A. Stemmer</td>
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</tbody>
</table>

Abstract

From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures. Special emphasis on the emerging field of molecular electronic devices.

Objective

Familiarize students with basic science and engineering principles governing the nano domain.

Content

The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Prerequisites

Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum

From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale

Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures.

Literature


Prerequisites / notice

Course format:

- Lectures and Mini-Review presentations: Thursday 10-13
- Homework: Mini-Review (compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.
**Computational Neuroimaging**

**Prerequisite:** Successful completion of course "Methods & Models for fMRI Data Analysis", "Translational Neuroimaging" or "Computational Psychiatry"

**Objective**

1. Consolidation of theoretical knowledge (obtained in the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimaging', 'Computational Psychiatry') in a practical setting.

2. Acquisition of practical problem solving strategies for computational modeling of neuroimaging data.

**Content**

This seminar teaches problem solving skills for computational neuroimaging, based on joint analyses of neuroimaging and behavioural data. It deals with a wide variety of real-life problems that are brought to this meeting from the neuroimaging community at Zurich, e.g. mass-univariate and multivariate analyses of fMRI/EEG data, or generative models of fMRI, EEG, or behavioural data.

**Prerequisites / notice**

The participants are expected to have successfully completed at least one of the following courses: 'Methods & models for fMRI data analysis', 'Translational Neuroimaging', 'Computational Psychiatry'.

**Literature**

Will be indicated during the lecture.

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**Methods & Models for fMRI Data Analysis**

**Objective**

2V

**Content**

This course teaches methods and models for fMRI data analysis, covering all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, statistical inference, multiple comparison corrections, event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data.

**Prerequisites / notice**

This course teaches state-of-the-art methods and models for fMRI data analysis in lectures and exercises. It covers all aspects of statistical parametric mapping (SPM), incl. preprocessing, the general linear model, frequentist and Bayesian inference, multiple comparison corrections, and event-related designs, and Dynamic Causal Modelling (DCM), a Bayesian framework for identification of nonlinear neuronal systems from neurophysiological data. A particular emphasis of the course will be on methodological questions arising in the context of clinical studies in psychiatry and neurology. Practical exercises serve to consolidate the skills taught in lectures.

**Literature**

Will be indicated during the lecture.
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

### Major in Bioengineering

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0965-00L</td>
<td>Micro and Nano-Tomography of Biological Tissues</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Stampanoni, F. Marone Wellof</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications</td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Synchrotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.</td>
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</tr>
<tr>
<td><strong>Lecture notes Literature</strong></td>
<td>Will be indicated during the lecture.</td>
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<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4 credits</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are working at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across disciplinary boundaries.</td>
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<tr>
<td><strong>Lecture notes Literature</strong></td>
<td>All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.</td>
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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W</td>
<td>4 credits</td>
<td>3V</td>
<td>K. Manlura, M. Rottmar, M. Zenobi-Wong</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.</td>
<td></td>
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</tr>
<tr>
<td><strong>Objective</strong></td>
<td>The course covers the following topics: 1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials. 2. The concept of biocompatibility. 3. Introduction into methodology used in biomaterials research and application. 4. Introduction to different material classes in use for medical applications.</td>
<td></td>
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</tr>
<tr>
<td><strong>Content</strong></td>
<td>Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.</td>
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</tbody>
</table>

| Lecture notes | Handouts are deposited online (moodle). |
Biomedical Engineering will cover the latest biotechnological advances as well as their industrial implementation to the field of medical devices and technologies.

Abstract

Biomedical Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective

Biomedical Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content


Lecture notes

Handout during the course.

Practical Work

The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Objective

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

Electives

376-1622-00L Practical Methods in Tissue Engineering (offered in the Autumn Semester) and 376-1624-00L Practical Methods in Biofabrication (offered in the Spring Semester) are mutually exclusive to be eligible for credits.

Biomedical Engineering

Abstract

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Objective

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

Content


Lecture notes

Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://ibb.ethz.ch/education/biomedical-engineering.html

Biominalization

Abstract

The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biominalization.
1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

Lecture notes
Script with more than 600 pages with many illustrations will be distributed free of charge.

Content
Biominalization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biominerals (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra- extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolarians and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

Prerequisites / notice
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

Literature
3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003

Objective
The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

Prerequisites / notice
A Windows laptop (or Windows on Mac) is required for certain of the lab modules.

Prerequisites / notice
A Windows laptop (or Windows on Mac) is required for certain of the lab modules.

Objective
Practical exercises on topics including sterile cell culture, light microscopy and histology, and biomaterials are covered. Practical work on manufacturing and evaluating hydrogels and scaffolds for tissue engineering will be performed in small groups. In addition to practical lab work, the course will teach skills in data acquisition/analysis.

Objective
As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

Objective
The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis. The atomic morphologies of the samples are described by the more complex dynamic theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation phenomena that reflect the internal structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Objective
Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical laws have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relationship between cell morphology and function.

Objective
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

Objective
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

Objective
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.
Abstract
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

Objective
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

Content
L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

Literature
- Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)
## Major in Bioelectronics

### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0604-00L</td>
<td>MicroRobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson, N. Shamsudhin</td>
</tr>
</tbody>
</table>

**Abstract**
MicroRobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

**Objective**
The objective of this course is to expose students to the fundamental aspects of the emerging field of microRobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

**Content**
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microRobots

**Prerequisites / notice**
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

**Lecture notes**
The lecture will be taught in English.

### Biomedical Engineering

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0386-00L</td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

**Objective**
Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.

**Content**

**Lecture notes**
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

AND

https://lbb.ethz.ch/education/biomedical-engineering.html

### Introduction to Neuroinformatics

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6</td>
<td>2V+1U+1A</td>
<td>V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens</td>
</tr>
</tbody>
</table>

**Abstract**
The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

**Objective**
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

**Content**
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

### Biocompatible Materials

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>376-1714-00L</td>
<td>Biocompatible Materials</td>
<td>W</td>
<td>4</td>
<td>3V</td>
<td>K. Maniura, M. Rottmar, M. Zenobi-Wong</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

Lecture notes
Handouts are deposited online (moodle).

Literature

(available online via ETH library)

Handouts and references therein.

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Bioelectronics and Biosensors

**Abstract**
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Objective**

During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

**Content**

L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

**Literature**
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

**Prerequisites / notice**
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

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### Practical Work

**Number**

<table>
<thead>
<tr>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>465-0800-00L Practical Work</td>
<td>O</td>
<td>4</td>
<td>external organisers</td>
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</tr>
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</table>

**Abstract**
The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

**Objective**
The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>W</td>
<td>6</td>
<td>2V+3U</td>
<td>T. Delbrück, G. Indiveri, S.-C. Liu</td>
</tr>
</tbody>
</table>

Information for UZH students:
Enrollment to this course unit only possible at ETH. No enrollment to module INI404 at UZH.
Please mind the ETH enrollment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html

Abstract
This course covers analog circuits with emphasis on neumorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding of the characteristics of neumorphic circuit elements.

Content
Neuroorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Prior knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for field analysis and treatment of small projects. Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for field physical modelling and simulation. Ability to develop own simple field simulation programs, to select an appropriate field solver for a given problem, to perform field simulations, to evaluate the obtained results, and to interactively improve the models until sufficiently accurate results are obtained.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Smajc</td>
</tr>
</tbody>
</table>

Abstract
This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Objective
Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability to develop own simple field simulation programs, to select an appropriate field solver for a given problem, to perform field simulations, to evaluate the obtained results, and to interactively improve the models until sufficiently accurate results are obtained.

Content
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM), The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HP-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or choose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

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<tr>
<th>Number</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
</tbody>
</table>

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective
Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departaments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Content
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0674-00L</td>
<td>Physics in Medical Research: From Atoms to Cells</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>B. K. R. Müller</td>
</tr>
</tbody>
</table>

Abstract
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X-rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopies.

<table>
<thead>
<tr>
<th>529-0837-01L</th>
<th>Biomicrofluidic Engineering</th>
<th>W</th>
<th>6 credits</th>
<th>3G</th>
<th>A. de Mello</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants limited to 25.</td>
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</table>

Abstract

Microfluidics describes the behaviour, control and manipulation of fluids geometrically constrained within sub-ul environments. Microfluidic devices enable physical and chemical processes to be controlled with exquisite precision and in an fast and efficient manner. This course introduces the underlying concepts, features and applications of microfluidic systems in the chemical and life sciences.

We will investigate the theoretical concepts behind microfluidic device operation, the methods of microfluidic device manufacture and the application of microfluidic architectures to important problems faced in modern day chemical and biological analysis.

A central component of this course is a research project. This will allow students to develop a practical understanding of the benefits of miniaturization in chemical and biological experimentation. Projects will be performed in groups of between four and six students and will include both experimental and simulation aspects. Each group, under the guidance of a mentor, will plan and execute a novel research project. The results of this activity will be disseminated through an "academic-style" research article and a "conference-style" oral presentation. Course grades will be evaluated through both a written exam and the project grade.

Content

Specific topics covered in the course include, but are not limited to:

1. Theoretical Concepts
   - Scaling laws, features of thermal/mass transport, diffusion, basic description of fluid flow in small volumes, microfluidic mixing strategies.
2. Microfluidic Device Manufacture
   - Basic principles of conventional lithography of rigid materials, ‘soft’ lithography, polymer machining (injection molding, hot embossing, and 3D-printing).
3. Electrokinetics
   - Principles of electrophoresis, electroosmosis, high performance capillary electrophoresis, electrokinetic scaling laws, chip-based electrophoresis and isoelectric focusing.
4. Mass Transfer Phenomena
   - Key features of mass transport in microfluidic systems, diffusive transport, diffusion-convection, Péclet number, Taylor-Aris diffusion, chaotic mixing and Damkőhler numbers.
5. Heat Transfer Phenomena
   - Key features of thermal transport in microfluidic systems, conduction, convection, heat transfer by convection in internal flows, heat transfer processes in microfluidic devices.
6. Microfluidic Systems for Materials Synthesis
   - Microfluidic reactors for the controlled synthesis of colloidal nanomaterials, advanced automation for bespoke materials discovery & characterization.
7. Point-of-Care Diagnostics
   - Microscale tools for diagnostics, challenges associated with point-of-care (PoC) diagnostic testing, requirements for PoC devices, common PoC device formats, applications of PoC diagnostics in the developing world.
8. Microscale DNA Amplification
   - Amplification and analysis of nucleic acids using batch, continuous flow and droplet-based microfluidic reactors.
9. Small Volume Molecular Detection
   - Spectroscopic approaches for analyte detection in small volumes with a particular focus on single molecule detection.
10. Droplets and Segmented Flows
    - Formation, manipulation and use of liquid/liquid segmented flows in chemical and biological experimentation.
11. Single Cell Analysis
    - Applications of microfluidic tools in cellular analysis, flow cytometry, enzymatic assays and single cell analysis.

Lecture notes

Lecture handouts, background literature, problem sheets and notes will be provided electronically through the course Moodle site.

Literature

There is no set text for the course. All relevant literature will be provided electronically through the course Moodle site.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Decision-making</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
<td>assessed</td>
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</tbody>
</table>

### Biological Engineering and Biotechnology

**Number**: 636-0108-00L  
**Title**: Biological Engineering and Biotechnology  
**Type**: W  
**ECTS**: 6 credits  
**Hours**: 3V  
**Lecturers**: M. Fussenegger

**Abstract**: Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Objective**: Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

**Content**:  
1. Insight Into The Mammalian Cell Cycle. Cycling, The Balance Between Proliferation and Cancer - Implications For Biopharmaceutical Manufacturing.  
2. The Licence To Kill. Apoptosis Regulatory Networks - Engineering of Survival Pathways To Increase Robustness of Production Cell Lines.  
5. From Target To Market. An Antibody’s Journey From Cell Culture to The Clinics.  
6. Biology and Malign Applications. Do Life Sciences Enable the Development of Biological Weapons?  
7. Functional Food. Enjoy your Meal!  

**Lecture notes**: Handout during the course.

### Major in Neuroinformatics

#### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U+1A</td>
<td>V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens</td>
</tr>
</tbody>
</table>

**Abstract**: The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

**Objective**: Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neuronal computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enforcements and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

**Content**: This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

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<tbody>
<tr>
<td>227-0393-10L</td>
<td>Bioelectronics and Biosensors</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>J. Vörös, M. F. Yanik</td>
</tr>
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</table>

**Abstract**: The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Objective**: During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

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Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).
This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:

1) The number of participants is limited to 120 students (MSc and PhDs).

2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

### Practical Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>465-0800-00L</td>
<td>Practical Work</td>
<td>O</td>
<td>4 credits</td>
<td></td>
<td>external organisers</td>
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</table>

Abstract: The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialisation. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

Objective: The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialisation program towards the solution of a focused problem.

### Electives

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>W</td>
<td>6 credits</td>
<td>2+3U</td>
<td>T. Delbrück, G. Indiveri, S.-C. Liu</td>
</tr>
</tbody>
</table>

Information for UZH students:

- Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.
- Please mind the ETH enrolment deadlines for UZH students: [https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html](https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html)

Abstract: This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective: Understanding of the characteristics of neuromorphic circuit elements.

Content: Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature: S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice: Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>376-1791-00L</td>
<td>Introductory Course in Neuroscience (University of Zurich)</td>
<td>W</td>
<td>2 credits</td>
<td>2V</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

UZH Module Code: SPV0Y005

Mind the enrolment deadlines at UZH: [https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html](https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html)

Abstract: The course gives an introduction to human and comparative neuroanatomy, molecular, cellular and systems neuroscience.

Objective: The course gives an introduction to the development and anatomical structure of nervous systems. Furthermore, it discusses the basics of cellular neurophysiology and neuropharmacology. Finally, the nervous system is described on a system level.


Prerequisites / notice: For doctoral students of the Neuroscience Center Zurich (ZNZ).

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<tr>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>J. Smajic</td>
</tr>
</tbody>
</table>
### Abstract

This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

### Objective

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

### Content

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnet-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

#### 227-1051-00L Systems Neuroscience (University of Zurich)

**Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.**

- **Number of participants limited to 12.**
- **A Windows laptop (or Windows on Mac) is required for certain of the lab modules.**
- **Prerequisites / notice**

#### 227-0965-00L Micro and Nano-Tomography of Biological Tissues

- **Abstract**
  - The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.
  - Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

- **Objective**
  - Synchrontron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the macro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

- **Content**
  - The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

- **Lecture notes**
  - Will be indicated during the lecture.

#### 376-1622-00L Practical Methods in Tissue Engineering

The goal of this course is to teach MSc students the necessary skills for doing research in the fields of tissue engineering and regenerative medicine.

- **Prerequisites / notice**

#### 376-1714-00L Biocompatible Materials

- **Abstract**
  - Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

- **Objective**
  - The course covers the following topics:
    1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
    2. The concept of biocompatibility.
    3. Introduction into methodology used in biomaterials research and application.
    4. Introduction to different material classes in use for medical applications.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**

Handouts are deposited online (moodle).

**Literature**

- Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM)/ types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra- and extracellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / silification in diatoms, radiolaria and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere/ evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

**Objective**

The practical work is aimed at training the student’s capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

### Electives

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<thead>
<tr>
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<tbody>
<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
<td>4</td>
<td>4V</td>
<td>V. Vogel, further lecturers</td>
</tr>
</tbody>
</table>

Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective

Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within manmade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

402-0674-00L Physics in Medical Research: From Atoms to Cells W 6 credits 2V+1U B. K. R. Müller

Abstract
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

Objective
The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

227-0393-10L Bioelectronics and Biosensors W 6 credits 2V+2U J. Vörös, M. F. Yanik

Abstract
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

Objective
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field
Content

L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits,
- differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index,
- Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of
- concentration, valence, reactants-products, etc.).

376-1353-00L Nanostructured Materials Safety W 2 credits 1V P. Wick
Abstract Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin
and intravenous injection
Objective Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide
knowledge to design safer materials
Lecture notes Handouts provided during the classes and references therein as well as primary literature as case studies will be posted to the course
website
Prerequisites / notice course “Introduction to Toxicology”

376-0945-00L Cell and Molecular Biology for Engineers I W 3 credits 2G C. Frei
Abstract This course is part I of a two-semester course.
The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus
will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined
with results from recent research and technological innovations in biology.
Objective After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to
modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.
Content Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic
biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell
cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II).
For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication.
These written documents will be graded and count as 40% for the final grade.

Lecture notes Scripts of all lectures will be available.
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material: 

- F. Allain, S. Jonas
- T. Vaughan

This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students.

### Objective

Basics of molecular biology and biophysics in in view of the special interest of students in physics.

### Content

This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students.

- The topics include: The molecules of life - properties of biological macromolecules. Discussion of structure and function of proteins, quantitative description molecular interactions and of enzyme function.
- Introduction to methods to study biological macromolecules: purification techniques, optical spectroscopy, X-ray crystallography, electron microscopy (EM) and nuclear magnetic resonance (NMR) spectroscopy.
- Introduction to the genetic system of E.coli bacteria: DNA, RNA and protein biosynthesis (transcription and translation) and biotechnological applications.

### Lecture notes

Additional documentation in support of text book

### Prerequisites / notice

Small classes with active participation of students

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### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | not assessed |
| | Decision-making | assessed |
| | Media and Digital Technologies | not assessed |
| | Problem-solving | assessed |
| | Project Management | not assessed |
| Domain C - Social Competencies | Communication | not assessed |
| | Cooperation and Teamwork | assessed |
| | Customer Orientation | not assessed |
| | Leadership and Responsibility | not assessed |
| | Self-presentation and Social Influence | not assessed |
| | Sensitivity to Diversity | not assessed |
| | Negotiation | not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | not assessed |
| | Self-direction and Self-management | not assessed |

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### 551-1601-00L Biophysics of Biological Macromolecules

**W** 6 credits  2V+1U  F. Allain, S. Jonas

**Abstract**

This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students.

**Objective**

Basics of molecular biology and biophysics in in view of the special interest of students in physics.

**Content**

This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students.

- The topics include: The molecules of life - properties of biological macromolecules. Discussion of structure and function of proteins, quantitative description molecular interactions and of enzyme function.
- Introduction to methods to study biological macromolecules: purification techniques, optical spectroscopy, X-ray crystallography, electron microscopy (EM) and nuclear magnetic resonance (NMR) spectroscopy.
- Introduction to the genetic system of E.coli bacteria: DNA, RNA and protein biosynthesis (transcription and translation) and biotechnological applications.

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### 636-0017-00L Computational Biology

**W** 6 credits  3G+2A  T. Vaughan

**Abstract**

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

**Objective**

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- * stochastic models in molecular evolution
- * phylogenetic & phylodynamic inference
- * maximum likelihood and Bayesian statistics

**Content**

Attendees will apply these concepts to a number of applications yielding biological insight into:

- * epidemiology
- * pathogen evolution
- * macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

**Prerequisites / notice**

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-B SSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date. For the Zurich-based students without R experience, we recommend the R course at D-BSSE.

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### Practical Work

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</table>

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The practical work is designed to train the students in the solution of a specific problem and provides insights in the field of the selected MAS specialization. Tutors propose the subject of the project, the project plan, and the roadmap together with the student, as well as monitor the overall execution.

The practical work is aimed at training the student's capability to apply and connect specific skills acquired during the MAS specialization program towards the solution of a focused problem.

### Electives

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<td>327-1101-00L</td>
<td>Biomineralization</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>K.-H. Ernst</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.</td>
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<tr>
<td>Objective</td>
<td>The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biomolecules with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.</td>
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<td>Content</td>
<td>Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) / types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biomolecules (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / structure of bone, teeth (vertebrates and invertebrates) and mollusk shells / calcification / siltification in diatoms, radiolari and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.</td>
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<tr>
<td>Lecture notes</td>
<td>Script with more than 600 pages with many illustrations will be distributed free of charge.</td>
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<td></td>
<td>3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy &amp; Geochemistry Vol. 54, 2003</td>
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<tr>
<td>Prerequisites / notice</td>
<td>No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.</td>
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<tr>
<td>376-1103-00L</td>
<td>Frontiers in Nanotechnology</td>
<td>W</td>
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<td>V. Vogel, further lecturers</td>
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<td>Abstract</td>
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<td>The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.</td>
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<tr>
<td>402-0674-00L</td>
<td>Physics in Medical Research: From Atoms to Cells</td>
<td>W</td>
<td>6</td>
<td>B. K. R. Müller</td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitelial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.</td>
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</table>
The seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure’s shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopsies.

535-0423-00L  Drug Delivery and Drug Targeting

| Objective | The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria. |
| Content | The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems. |

Further references will be provided in the course.


551-1615-00L  NMR Methods for Studies of Biological Macromolecules

| Prerequisites: Basic knowledge in biological NMR spectroscopy. |
| Objective | Seminar series on technical aspects of high resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules. This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution. |
| Content | Seminar series on technical aspects of high-resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules. This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution. |

551-1619-00L  Structural Biology

| Objective | Seminar series on technical aspects of high resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules. This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution. |
| Content | Seminar series on technical aspects of high-resolution nuclear magnetic resonance (NMR) spectroscopy with biological macromolecules. This seminar series is targeted at Master students and PhD students conducting research projects in the field of biomolecular NMR in solution. |

Abstract
The course consists of a series of research seminars on Structural Biology, Biochemistry and Biophysics, given by both scientists of the National Center of Competence in Research (NCCR) in Structural Biology and external speakers. Information on the individual seminars is provided on the following websites:
http://www.structuralbiology.uzh.ch/educ002.asp
http://www.biol.ethz.ch/dbiol-cal/index

Objective
The goal of this course is to provide doctoral and postdoctoral students with a broad overview on the most recent developments in biochemistry, structural biology and biophysics.

551-0307-00L Molecular and Structural Biology I: Protein Structure and Function

W 3 credits 2V  R. Glockshuber, K. Locher, E. Weber-Ban

Abstract
Biophysics of protein folding, membrane proteins and biophysics of membranes, enzymatic catalysis, catalytic RNA and RNAi, current topics in protein biophysics and structural biology.

Objective
Understanding of structure-function relationships in proteins and in protein folding, detailed understanding of biophysics and physical methods as well as modern methods for protein purification and microanalytics.

Lecture notes
Scripts on the individual topics can be found under http://www.mol.biol.ethz.ch/teaching.

Literature
Basics:
- Creighton, T.E., Proteins, Freeman, (1993)
- Fersht, A., Enzyme, Structure and Mechanism in Protein Science (1999), Freeman.

Current topics: References will be given during the lectures.

636-0108-00L Biological Engineering and Biotechnology

W 4 credits 3V  M. Fussenegger

Abstract
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Objective
Biological Engineering and Biotechnology will cover the latest biotechnological advances as well as their industrial implementation to engineer mammalian cells for use in human therapy. This lecture will provide forefront insights into key scientific aspects and the main points in industrial decision-making to bring a therapeutic from target to market.

Content

Handout during the course.

227-2037-00L Physical Modelling and Simulation

W 6 credits 4G  J. Smajic

Abstract
This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.

Objective
Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation.

Content
The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

MAS in Medical Physics - Key for Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recom.</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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</table>

Key for Hours

<table>
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<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
MAS in Future Transport Systems
Four-semester, part-time MAS programme.

Start of the next course: Spring Semester 2023.


► Major in Systemic Aspects of Future Transport
The Major in "Systemic Aspects of Future Transport" takes place only in Spring Semester

Start of the next course: Spring Semester 2023
Course duration: Six months part time
Periodicity: Every two years

► Major in Technology Potential
The Major in "Major in Technology Potential" takes place only in Autumn Semester

Start of the next course: Autumn Semester 2021
Course duration: Six months part time
Periodicity: Every two years

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The module provides a foundation in the current situation and short- and middle-term development directions of powertrain and automotive engineering in the context of passenger &amp; goods transport. Corresponding energy sources and resulting consequences for the energy system are addressed. Participants will be enabled to identify potentials of these technologies and apply them to concrete problems.</td>
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<tr>
<td>Objective</td>
<td>Familiarity with conventional and alternative powertrain and automotive systems for future sustainable mobility, and the ability to identify and deploy their potential to address concrete problems.</td>
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<tr>
<td>Content</td>
<td>Drive component efficiency rates and core fields - Drive and non-drive energy flow / Vehicle &quot;driving resistance&quot; - Energy chains (operating power only) and CO2 emissions to primary energy</td>
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<tr>
<td>Lecture notes</td>
<td>Distributed at start of module</td>
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<tr>
<td>Literature</td>
<td>Distributed at start of module</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Announced to students of the of the MAS / CAS at the beginning of the term</td>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The digital revolution, spatial information and communication systems in particular, have a significant influence on the development of new transport systems. Participants acquire an in-depth understanding of the functionality and application potential of spatial information systems and services and of communication technologies for deployment in future transport systems and applications.</td>
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<tr>
<td>Objective</td>
<td>Familiarity with information and communication technologies (ICT) and spatial information technologies, and the ability to identify and utilise their potential to address concrete problems.</td>
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<tr>
<td>Content</td>
<td>Functionality and application of geographic information systems (GIS) to represent and analyse transport systems (acquire, model, analyse and visualise geodata) - Deployment potentials of GIS and ICT for efficient transport solutions (tangible, non-tangible) - Functionality and application of mobile spatial information technologies in future transport systems - Technical aspects of information and communication technologies (ICT) - Modelling, simulation and assessment of traffic behaviour - Basics of autonomous driving - Legal aspects of geodata - Applications: Traffic behaviour in Switzerland; location based services for energy-efficient behaviour; GIS for the Zurich traffic system (multimodal)</td>
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<tr>
<td>Lecture notes</td>
<td>Distributed at start of module</td>
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<tr>
<td>Literature</td>
<td>Distributed at start of module</td>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The module provides a solid introduction to integrated technology assessment with regard to economic, ecological and social criteria. It introduces life cycle assessment (LCA), cost assessment, risk assessment and multi-criteria decision analysis. It also presents scenario analyses based upon energy-economic models which explicitly represent transport and energy-supply technologies.</td>
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<tr>
<td>Objective</td>
<td>An overview of suitable methods for analysing and evaluating technical systems (transport systems) and the ability to choose among them to address concrete problems</td>
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</tr>
</tbody>
</table>
Content
(1) Introduction to and overview of integrated assessment
- Current status of transport in Switzerland and internationally
- Scope and goals of integrated assessment
- Sustainability: concept and practical implementation via criteria and indicators
- Overview of concepts and implementation methods

(2) Selected methods for assessing transport technologies and their application to current and future options
- Ecobalance / life cycle assessment (LCA)
- Location-specific assessment of health hazards and environmental pollution
- Risk analysis
- Internal cost assessment
- External cost assessment

(3) Integrated assessment of transport technologies
- Overall costs (internal and external)
- Multi-criteria analysis

(4) Analysis of transport scenarios
- Scenarios, influencing factors, policy and sustainability
- Approaches to scenario modelling
- Global mobility scenarios: examples
- Transport scenarios for Switzerland using energy system models

Lecture notes
Distributed at start of module

Literature
Distributed at start of module

Prerequisites / notice
Announced to students of the of the MAS / CAS at the beginning of the term

166-0203-00L Energy Carrier for the Mobility of the Future  O 3.5 credits 3G C. Bach
Abstract
The module includes the supply of the road mobility of the future with renewable energy. The generation, transport, processing, transfer of energy to the vehicles (refueling, charging) and the energetic evaluation are presented. Electricity, hydrogen, biogenic and synthetic fuels are considered.
Objective
The aim of the module is a detailed energetic and technical understanding of the supply of road vehicles with renewable energy. Graduates know the primary energy production as well as the end energy processing of the different energy carrier concepts. In addition, they know the legal CO2 requirements for vehicle registration and are able to qualitatively assess the impact on the Swiss energy system.

166-0290-00L CAS Thesis on Technology Potentials  O 3 credits 5D M. A. Streicher-Porte
Abstract
The participants, in heterogeneous teams, deal with a current problem from the topics of the CAS Technology Potentials.
Objective
- Deal with a specific problem from the CAS Technology Potentials subject area.
- Be able to work interdisciplinary and across sectors, where appropriate together with relevant other parties.
- Communicate the results appropriately.

166-0490-00L Master’s Thesis O 15 credits 27D M. A. Streicher-Porte
Only for MAS in Future Transport Systems.
Abstract
Individually and independently, students address a practice-related problem in the area of future transport systems. To do this they deploy, under the supervision of an expert, what they have learned in the MAS programme. They set out the problem, the procedure and the solution in a written report which they present and defend in front of a specialist audience.
Objective
- Ability to draw up solutions in the context of future transport systems.
- Ability to communicate these solutions in a manner suited to a particular target audience.
Content
- Introductory colloquium: Working scientifically and presenting a project idea
- Individual and independent work on a problem selected by the participant
- Interim colloquium: Presentation of the status quo
- Individual supervision by the lecturer
- Compilation of the written thesis and preparation of the presentation
- Examination colloquium: Presentation and defence

Lecture notes Distributed at start of module
Literature Distributed at start of module
Prerequisites / notice Announced to students of the of the MAS at the beginning of the term.

MAS in Future Transport Systems - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Lectures and Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>115-0500-00L</td>
<td>Preliminary Course: Introduction to Swiss Spatial Planning</td>
<td>O</td>
<td>3 credits</td>
<td>3G</td>
<td>D. Jerjen, A. Schneider</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Tasks of spatial planning; objectives and principles; instruments of spatial planning; federal planning; cantonal structural planning; constructing outside of building zones; communal planning; land use planning; compensation of benefits released by planning; environmental protection and spatial planning; energy and spatial planning; densification with quality; case studies and exercises.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>The preliminary course introduces students to the fundamentals of formal spatial planning in Switzerland. It gives a first overview over background and context of spatial planning as well as instruments of spatial planning.</td>
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<tr>
<td>115-0500-01L</td>
<td>Introduction to the Programme and Study Project 1</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>M. Nollert, J. Van Weizemael</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Discussion of the individual basic understanding of spatial planning; Personal preconditions for and expectations of MAS-program; program concept; knowledge portfolio and learning contract; work environments and tools; introduction to study project 1 with excursion; theoretical background for interdisciplinary team work.</td>
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<td><strong>Objective</strong></td>
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<td>Aim of the first week is, to give participants a first overview over the programme and the first study project, to clarify the above mentioned topics of the individual positions and expectations towards the course as well as to acquire basic knowledge about teamwork.</td>
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<tr>
<td>115-0501-00L</td>
<td>Lecture Week 01: Spatial Planning: Tasks and Methods</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>M. Nollert</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Current and future significant tasks of Spatial Planning in Switzerland. In addition to the existing inner development of settlements, the importance of new challenges such as climate adaptation and the implementation of the mobility turn is rising. What they have in common is the need of methods and instruments for exploring, clarifying and solving complex tasks.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td>The aim of the course is the acquaintance and the comprehension of tasks, methods and instruments of spatial planning in Switzerland and to discuss them in the light of future challenges. In particular, the methodological modules of the course form an essential basis for working on the two study projects of the MAS programme.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>starting point of the course are existing and future spatially significant tasks. In addition to the presentation and description of typical challenges using case studies, the focus is also on the understanding of context and relationships as well as constants and variables of spatial development. Different types of tasks and the resulting consequences for their clarification and solution are also discussed.</td>
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<td>The tasks are contrasted with a brief overview of existing spatial planning instruments in Switzerland. On the one hand, the aim is to develop a common understanding of the formal and informal procedures and instruments of spatial planning; on the other hand, these are also to be discussed with regard to their effectiveness for current and future challenges.</td>
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<td>At the centre of the teaching unit is the teaching and methodological basis for exploring, clarifying and solving complex issues. These refer to the questions and pitfalls of perceiving and dealing with complexity, to methodological elements of processes for clarifying difficult spatially significant tasks with a large number of actors involved, as well as methods of situation assessment, design and decision-making as a basis for developing solutions.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<td>A reader with central elements of the course and background information will be provided</td>
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<td><strong>Taught competencies</strong></td>
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<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
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<td>Decision-making</td>
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<td>Problem-solving</td>
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<td>Domain C - Social Competencies</td>
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<td>Domain D - Personal Competencies</td>
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<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
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<tr>
<td>115-0502-00L</td>
<td>Lecture Week 02: Urban Planning and Urban Design I</td>
<td>W</td>
<td>2 credits</td>
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<td>S. Kretz, C. Salewski</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Contemporary urbanization phenomena and urban design methods and tools. Lectures are accompanied by urban design exercises. Introduction to current challenges and methods in urban design, to theories of urban planning and to exemplary urban design projects.</td>
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<tr>
<td>115-0503-00L</td>
<td>Lecture Week 03: Landscape Architecture</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>G. Vogt</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Methods, tools and processes in large scale landscape architectural design. On the basis of a case study, «Basel», we shall discuss these themes in lectures and practical exercises. The design-led approach will be extended with a series of talks that will establish a theoretical grounding in current issues of landscape- and urban design.</td>
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<td><strong>Objective</strong></td>
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<td>On the basis of theoretical foundations the one-week teaching block explains the possibillies and methods of design at different stages of the process. The students will become sensitive to current and future issues and approaches of landscape on a large scale, with the aim that they will engage with critical debate on the topic and take their own position.</td>
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<tr>
<td>115-0504-00L</td>
<td>Lecture Week 04: Landscape and Environmental Planning</td>
<td>W</td>
<td>2 credits</td>
<td>1G</td>
<td>A. Grét-Regamey, U. Wissen Hayek</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>Discussion of the proposition of sustainability in landscape and environmental planning; comprehending landscape development with a system dynamics approach; planning of landscape development across cantonal and communal boundaries; negotiating various stakeholder interests based on the example of current practical cases; instruments and approaches for sustainable landscape development.</td>
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<td><strong>Objective</strong></td>
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<td>Overview of tasks of landscape and environmental planning as well as essential theories; insights in planning approaches and application of new instruments related to current problems for a sustainable landscape development.</td>
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<tr>
<td>Number</td>
<td>Title</td>
<td>Type</td>
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<td>Hours</td>
<td>Lecturers</td>
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<tr>
<td>115-0701-00L</td>
<td>Study Project 1 (Part 1)</td>
<td>O</td>
<td>0 credits</td>
<td>10U</td>
<td>M. Nollert, F. Argast, O. Hagen, A. Näf-Clasen, M. Sandtner</td>
</tr>
</tbody>
</table>

Project 1 takes 2 semesters, continuation in the following spring semester, taking part 2 is obligatory.

Abstract
Development of strategies for sustainable development in Basel: spatial planning analysis of the situation (goals and problems, potentials and risks, strengths and weaknesses); concept design (goals and measures); program development (objective and temporal priorities); preparation for implementation (instruments and procedures); independent group work.

Objective
Detect, assess and classify the main conflicts of spatial developments and detect need for planning action. Concentrate resources and design and evaluate different solutions and demonstrate their feasibility exemplarily. Recognize possibilities and limits of formal and informal planning and applying them practically. Efficient and interdisciplinary work in groups, using individual knowledge and skills of the group members optimally.

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### MAS in Spatial Planning - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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### Key for Hours

<table>
<thead>
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<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

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ECTS European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to
understand how a fluvial system functions, how to identify sediment sources and sinks, and how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Abstract

The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, and how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope model concepts like thresholds, equilibrium, criticality, to describe change.

For further information, contact Dr. Darcy Molnar (darcy.molnar@ifu.baug.ethz.ch)

Core Courses

Foundation courses: 12 credits have to be achieved.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>118-0101-00L</td>
<td>Water Resources Seminars</td>
<td>O</td>
<td>3</td>
<td>3S</td>
<td>D. Molnar, P. Burlando</td>
</tr>
<tr>
<td>Abstract</td>
<td>The Seminar Series features invited experts from a wide range of disciplines who present their experiences working with water related topics in international settings. The students are exposed to many different perspectives and are asked to apply the information they learn to specific case studies.</td>
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<tr>
<td>Objective</td>
<td>The Seminar Series provides students with background information on a wide range of topics related to water resources. Invited experts challenge the students to consider water resources and water resource management in new ways, using tools that have been successfully implemented in real case scenarios. The seminars include theory, interactive discussions, and the assessment of methodologies. Student participation is highly encouraged.</td>
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<tr>
<td>Content</td>
<td>The Seminar Series is aimed at offering students the opportunity to learn about water resources in a multi-disciplinary fashion, with a focus on international examples. Selected topics include: Water &amp; Climate Change, Water &amp; Sanitation, Water Management in Central Asia, Water &amp; Agriculture, Nature Based Solutions, Water Hazards (floods), Water &amp; Business, and Water Stewardship. For additional details see the course website <a href="https://mas-sw.etzh.ch/courses/courses/water-resources-seminars.html">https://mas-sw.etzh.ch/courses/courses/water-resources-seminars.html</a>.</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>For further information, contact Dr. Darcy Molnar (<a href="mailto:darcy.molnar@ifu.baug.ethz.ch">darcy.molnar@ifu.baug.ethz.ch</a>)</td>
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<tr>
<td>118-0114-00L</td>
<td>Nature-Based Solutions and Blue Green Infrastructure</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>D. Molnar, P. M. Bach</td>
</tr>
<tr>
<td>Abstract</td>
<td>Nature-based solutions (NbS) are effective means of addressing global societal challenges such as the need for water and food security, disaster risk reduction, and adaptation to climate change. Students are exposed to a variety of topics around NbS and Blue Green Infrastructure, gaining insight into how societies can incorporate ecosystem-based solutions to become more resilient and sustainable.</td>
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<tr>
<td>Objective</td>
<td>Nature-based solutions leverage water resources management to not only provide basic water servicing needs, but also a range of ecosystem services for the benefits of humans and the environment. At the urban and peri-urban level, multi-functional Blue Green Infrastructure solutions (inspired by nature-based concepts) are being developed that involve a broad range of stakeholders and a complex policy environment. The course will provide students with an overarching picture of how Nature-based solutions and Blue Green infrastructure are being used to make societies and cities greener, more resilient, climate-adaptive, more liveable, sustainable, and especially, how water resources management is being leveraged to accomplish this. Students will gain insight into suitable tools and approaches to navigating interactions between relevant stakeholders, hands-on experience through a scenario-based real-world project, a field visit to an urban case study, as well as insights from leading public and private sector experts in Nature-based Solutions and Blue Green Infrastructure.</td>
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<tr>
<td>Content</td>
<td>The course is designed to expose students to different ways of thinking across multiple disciplines, but with a focus on how, as future professionals, they can facilitate and provide tangible solutions that are multi-functional and accepted by a wide array of decision-makers. Selected topics include: (1) Understanding how Nature-based Solutions and Blue Green Infrastructure can be used to address global societal challenges, (2) understanding the need for different levels of planning in order to design effective solutions and policies that will ensure sustainable development, (3) identifying and understanding the function of suitable infrastructure to complement existing systems, (4) support tools and quantitative approaches for evidence-based performance evaluation, and (5) planning and decision-making around Nature-based solutions.</td>
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<tr>
<td>Lecture notes</td>
<td>There is no textbook. Learning materials consist of lectures, videos, and references provided by the instructors on the course Moodle page.</td>
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<tr>
<td>Literature</td>
<td>Literature consists of research papers and journal articles provided by the instructors on the course Moodle page.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Bachelor studies in environmental engineering or environmental sciences. For further information, contact the MAS coordinator, Darcy Molnar (<a href="mailto:darcy.molnar@ifu.baug.ethz.ch">darcy.molnar@ifu.baug.ethz.ch</a>)</td>
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Foundation Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0287-00L</td>
<td>River Basin Erosion</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>P. Molnar</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, and how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.</td>
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<tr>
<td>Content</td>
<td>The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial system change, using the right language and terminology to describe landforms. We will cover the main geomorphic concepts of landscape change, e.g. thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.</td>
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<tr>
<td>Lecture notes</td>
<td>There is no script.</td>
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</tr>
<tr>
<td>Literature</td>
<td>The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).</td>
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<tr>
<td>101-0267-01L</td>
<td>Numerical Hydraulics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Holzer</td>
</tr>
<tr>
<td>Abstract</td>
<td>In the course Numerical Hydraulics the basics of numerical modelling of flows are presented.</td>
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</tbody>
</table>

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The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which are partially programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Given in lecture

Lecture notes, powerpoints shown in the lecture and programs used can be downloaded. They are also available in German.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-presentation and Social Influence: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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102-0617-00L Basics and Principles of Radar Remote Sensing for Environmental Applications

W 3 credits 2G  I. Hajnsek

Abstract
The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.

Objective
At the end of the course the student has the understanding of
1. SAR basics and principles,
2. SAR polarimetry,
3. SAR interferometry and
4. environmental parameter estimation from multi-parametric SAR data

Content
The course is giving an introduction into SAR techniques, the interpretation of SAR imaging responses and the use of SAR for different environmental applications. The outline of the course is the following:
1. Introduction into SAR basics and principles
2. Introduction into electromagnetic wave theory
3. Introduction into scattering theory and decomposition techniques
4. Introduction into SAR interferometry
5. Introduction into polarimetric SAR interferometry
6. Introduction into bio/geophysical parameter estimation (classification/segmentation, soil moisture estimation, earth quake and volcano monitoring, forest height inversion, wood biomass estimation etc.)

Lecture notes
Handouts for each topic will be provided

Literature
Complete literature listing will be provided during the course.

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102-0215-00L Urban Water Management II

W 4 credits 2G  M. Maurer, P. Staufer

Abstract

Objective
Consolidation of the basic procedures for design and operation of technical networks in water engineering.

Content
Demand Side Management versus Supply Side Management
Optimierung von Wasserverteilnetzen
Kalkausfällung, Korrosion von Leitungen
Hygiene in Verteilsystemen
Siedlungshydrologie: Niederschlag, Abflussbildung
Instationäre Strömungen in Kanalisationen
Stofftransport in der Kanalisation
Einleitbedingungen bei Regenwetter
Versickerung von Regenwasser
Generelle Entwässerungsplanung (GEP)

Lecture notes
Written material will be available digital.

Prerequisites / notice
Prerequisite: Introduction to Urban Water Management

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701-1253-00L Analysis of Climate and Weather Data

W 3 credits 2G  C. Frei

Abstract
Does not take place this semester.

An introduction into methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of deterministic and probabilistic predictions, principal component analysis. Participants understand the theoretical concepts and purpose of methods, can apply them independently and know how to interpret results professionally.
Objective
Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.

Content
The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

Lecture notes
Documentation and supporting material:
- slides used during the lecture
- exercise sets and solutions
- R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

Literature
For complementary reading:

Prerequisites / notice
Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umwelt naturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

651-4031-00L Geographic Information Systems
W 3 credits 4G A. Baltensweiler, M. Hägeli-Golay
Number of participants limited to 60.

Abstract
Introduction to the architecture and data processing capabilities of geographic information systems (GIS). Practical application of spatial data modeling and geoprocessing functions to a selected project from the earth sciences.

Objective
Knowledge of the basic architecture and spatial data handling capabilities of geographic information systems.

Content
Theoretical introduction to the architecture, modules, spatial data types and spatial data handling functions of geographic information systems (GIS). Application of data modeling principles and geoprocessing capabilities using ArcGIS: Data design and modeling, data acquisition, data integration, spatial analysis of vector and raster data, particular functions for digital terrain modeling and hydrology, map generation and 3D-visualization.

Lecture notes
Introduction to Geographic Information Systems, Tutorial: Introduction to ArcGIS Pro

Literature


102-0468-10L Watershed Modelling
W 6 credits 4G P. Molnar

Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature
Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Prerequisites / notice
Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences), Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Elective Courses
Echelates: 6 credits has to be achieved.
## Content

The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

### Lecture notes

An Introduction to R. [http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf](http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf)

### Prerequisites / notice

As from FS 2019, subscribing via Mystudies should "automatically" make you a student participant of the Moodle course of this lecture, which is at [https://moodle-app2.let.ethz.ch/course/view.php?id=15518](https://moodle-app2.let.ethz.ch/course/view.php?id=15518)

### Literature

- **Mathematical Analysis**: J. Ghazoul
- **Physics of Glaciers**: M. Lüthi, F. T. Walter, M. Werder
- **Erosion and Sedimentation by Glaciers as a Function of Topography, Glacial Temperature, Sediment Balance, Sliding and Melt Water Runoff**: U. von Gunten
- **Processes and Landforms in Regions of Seasonal and Perennial Frost**: S. Hug, M. Berg, F. Hammes, U. von Gunten

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### Prerequisites / notice

- Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes
- Students need to be familiar with permafrost/rock glaciers, debris flows.

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### Literature

- **Water Resources and Drinking Water**: S. Hug, M. Berg, F. Hammes, U. von Gunten
- **Physics of Glaciers**: M. Lüthi, F. T. Walter, M. Werder
- **Foundations of Ecosystem Management**: J. Ghazoul, C. Garcia, J. Garcia Ulloa, A. Giger Dray

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### Prerequisites / notice

- Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

---

### Literature

- **Mathematical Analysis**: J. Ghazoul
- **Physics of Glaciers**: M. Lüthi, F. T. Walter, M. Werder
- **Erosion and Sedimentation by Glaciers as a Function of Topography, Glacial Temperature, Sediment Balance, Sliding and Melt Water Runoff**: U. von Gunten
- **Processes and Landforms in Regions of Seasonal and Perennial Frost**: S. Hug, M. Berg, F. Hammes, U. von Gunten

---

### Prerequisites / notice

- Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

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### Literature

- **Water Resources and Drinking Water**: S. Hug, M. Berg, F. Hammes, U. von Gunten
- **Physics of Glaciers**: M. Lüthi, F. T. Walter, M. Werder
- **Foundations of Ecosystem Management**: J. Ghazoul, C. Garcia, J. Garcia Ulloa, A. Giger Dray

### Prerequisites / notice

- Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
Objective

Students should be able to
a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales,
b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

Content

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

Lecture notes

No Script

Literature


701-0535-00L Environmental Soil Physics/Vadose Zone Hydrology W 3 credits 2V+1U A. Carminati, M. Dettling

Abstract

The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils/near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

Objective

Students are able to
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

Content

Week 1: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;

Week 2: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

Week 7: Unsatuated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip): outlook on unstable and preferential flow

Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project

Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow

Week 10: Root water uptake and transpiration

Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convolution-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

Week 12: Summary of lectures; solution of old exam

Week 13: Written semester-end exam

Week 14: Short presentations of Hydrus class projects; discussion of written exam

Supplemental textbook (not mandatory) -Introduction to Environmental Soil Physics, by: D. Hillel

401-0649-00L Applied Statistical Regression W 5 credits 2V+1U M. Detting

Abstract

This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content

The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.

The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.
The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

Domain D - Personal Competencies
- Self-direction and Self-management

701-1551-00L Sustainability Assessment W 3 credits 2G P. Krütli, D. Nef

No enrollment possible after October 1st, 2021.

Waiting list will be deleted October 1st, 2021.

The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

701-1644-00L Mountain Forest Hydrology W 5 credits 3G J. W. Kirchner

This course presents a process-based view of the hydrology, biogeochemistry, and geomorphology of mountain streams. Students learn how to integrate process knowledge, data, and models to understand how landscapes regulate the fluxes of water, sediment, nutrients, and pollutants in streams, and to anticipate how streams will respond to changes in land use, atmospheric deposition, and climate.

Students will have a broad understanding of the hydrological, biogeochemical, and geomorphological functioning of mountain catchments. They will practice using data and models to frame and test hypotheses about connections between streams and landscapes.

Streams are integrated monitors of the health and functioning of their surrounding landscapes. Streams integrate the fluxes of water, solutes, and sediment from their contributing catchment area; thus they reflect the spatially integrated hydrological, ecophysiological, biogeochemical, and geomorphological processes in the surrounding landscape. At a practical level, there is a significant public interest in managing forested upland landscapes to provide a reliable supply of high-quality surface water and to minimize the risk of catastrophic flooding and debris flows, but the scientific background for such management advice is still evolving.

Using a combination of lectures, field exercises, and data analysis, we explore the processes controlling the delivery of water, solutes, and sediment to streams, and how those processes are affected by changes in land cover, land use, and climate. We review the connections between process understanding and predictive modeling in these complex environmental systems. How well can we understand the processes controlling watershed-scale phenomena, and what uncertainties are unavoidable? What are the relative advantages of top-down versus bottom-up approaches? How much can "black box" analyses reveal about what is happening inside the black box? Conversely, can small-scale, micro-mechanistic approaches be successfully "scaled up" to predict whole-watershed behavior? Practical problems to be considered include the effects of land use, atmospheric deposition, and climate on streamflow, water quality, and sediment dynamics, illustrated with data from experimental watersheds in North America, Scandinavia, and Europe.
<table>
<thead>
<tr>
<th>Type</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Master's Thesis</td>
</tr>
</tbody>
</table>

**Abstract**: The purpose of this course is to provide fundamental background on the role of land surface processes (vegetation, soil moisture dynamics, land energy and water balances) in the climate system. The course consists of 2 contact hours per week, including lectures, project groups and computer exercises.

**Objective**: The students can understand the role of land processes and associated feedbacks in the climate system.

**Lecture notes**: Powerpoint slides will be made available.

**Prerequisites / notice**: Required reading will be specified at the first class session (with possible modifications as the semester proceeds). The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org and/or https://www.r-project.org/

**Content**: The course provides the second part of an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions. Note: This part builds on "Using R... (Part I)", but can be taken independently if the basics of R are already known.

**Prerequisites / notice**: Basic knowledge of R equivalent to "Using R... (part I)" (= 401-6215-00L) is a prerequisite for this course.

**Lecture notes**: An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

**Notice**: This part builds on "Using R... (Part I)", but can be taken independently if the basics of R are already known.

**Literature**: An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

**Key for Hours**

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
</tbody>
</table>

**ECFS**: European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
- Recommended, not eligible for credits
- Recommended, eligible for credits
- Courses outside the curriculum
- Suitable for doctorate
- Practical/laboratory course
- Independent project
- Diploma thesis
- Revision course / private study
**MAS in Urban and Territorial Design**

### Design Studio and Postproduction

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>078-0100-00L</td>
<td>Core Design and Research Studio I (EPFL)</td>
<td>O</td>
<td>16 credits</td>
<td>17G</td>
<td>external organisers</td>
</tr>
<tr>
<td></td>
<td>Only for MAS in Urban and Territorial Design</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Lecturers: P. Viganò with C. Fivet, L. Rossi and guests. The Core Studio will reflect on the “transition”, assuming its multiple dimensions (ecological, social and economic) and developing transcalar design operations in concrete territories. The territory of Greater Geneva will be the test-bed for radical design explorations of possible futures.</td>
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<td>Objective</td>
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<td></td>
<td>Different urban conditions will be considered in order to understand, read and manage the thick complexity of the contemporary habitat where densities, distances, relations and practices shape heterogeneous spaces and ecologies. Conceived as a place of interaction among disciplines, the studio also constitutes the main tool to develop interdisciplinarity within the design practice.</td>
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<td></td>
<td>Content</td>
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<td>A series of lectures will deal with ecology; the organism and its environment; population and community ecology; and biodiversity. Others lectures on design as knowledge production and on representation—GIS, video and photography—will be embedded within the activities of the studio. Fieldwork is integral to the design studio.</td>
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</table>

| 078-0101-00L | Postproduction I (EPFL)                                      | O    | 2 credits | 2G   | external organisers    |
|              | Only for MAS in Urban and Territorial Design               |      |          |      |                         |
|              | Abstract                                                   |      |          |      |                         |
|              | Lecturer: P. Viganò. The last period of the semester in January will consist of a post-production session, related to the results at EPFL. It mainly concerns the products of the Core Studio, but will also be implemented by the associated teaching. |
|              | Objective                                                  |      |          |      |                         |
|              | All research and design materials produced during the studio, courses and sessions (e.g. texts, maps, drawings, etc.) will be evaluated, edited and curated in a “Semester Report” by the core teaching team and a graphic designer. At the end, the “Report” will be available online. |

### Interdisciplinary Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>078-0200-00L</td>
<td>City, Habitat and Mobility (EPFL)</td>
<td>O</td>
<td>3 credits</td>
<td>3G</td>
<td>external organisers</td>
</tr>
<tr>
<td></td>
<td>Only for MAS in Urban and Territorial Design</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Lecturers: V. Kaufmann with L. Pattaroni. The course aims to understand the political and social conditions of urban lifestyles and mobilities patterns in order to explore the levers of action available to professionals to support the critical emergence of renewed urban models.</td>
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<td>Taking the form of a course - seminar, the proposed teaching aims to show the interest of methodologies from the social sciences of the city to develop critical urban and territorial design. Planned to last 12 weeks, it proposes to take up each week a theme related to the relation between city, habitat and mobility.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Each session is organized in two parts: (1) a presentation by one of the students of an article on the week’s theme, followed by a discussion, and (2) a presentation by the teaching team to identify the knowledge and debates of social sciences related to urban and territorial design issues. Two sessions will be devoted to field visits.</td>
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</table>

| 078-0201-00L | Building Design in the Circular Economy (EPFL)              | O    | 3 credits | 3G   | external organisers    |
|              | Only for MAS in Urban and Territorial Design               |      |          |      |                         |
|              | Abstract                                                   |      |          |      |                         |
|              | Lecturer: C. Fivet. The circular economy consists in maintaining the value of products as long as possible by extending or renewing their service life while minimizing resource depletion, waste and greenhouse gas emissions. The integration of these principles in the construction industry has many facets that often contradict each other. |
|              | Objective                                                  |      |          |      |                         |
|              | While introducing students to the concept of the circular economy and its applications to building design, the class provides ready-to-use techniques and aims at developing a critical mindset towards their use. Following a ‘flipped classroom’ methodology, the class devies into recent literature and practice by means of adversarial open debates. Examination consists in the writing of a short personal essay on a chosen topic and its oral defence. |
|              | Content                                                    |      |          |      |                         |

| 078-0202-00L | Urban Hydrology (EPFL)                                      | O    | 2 credits | 2G   | external organisers    |
|              | Only for MAS in Urban and Territorial Design               |      |          |      |                         |
|              | Abstract                                                   |      |          |      |                         |
|              | Lecturer: L. Rossi. This course addresses water management from a global point of view, including in particular the impacts of rain discharges on receiving environments. The qualitative aspects (risk of contamination) are considered as a priority, in parallel with the quantitative risks (floods). |
|              | Objective                                                  |      |          |      |                         |
|              | The course aims to understand the means and issues of management and maintenance of sewerage systems, finalized to the control of impacts in receiving environments, and more generally to raise the importance of hydraulic management in the urban and territorial project. |
|              | Content                                                    |      |          |      |                         |
|              | General introduction - Legislative aspects related to urban hydrology - Simplified design methods and technical solutions: from source control to solutions at the end of the network - Field visits |

### Urban Theory Sessions

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>078-0300-00L</td>
<td>Histories of Environment (EPFL)</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>external organisers</td>
</tr>
<tr>
<td></td>
<td>Only for MAS in Urban and Territorial Design</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Lecturers: S. Marot and guests. As a guiding principle that remains to be defined, the transition can be critically confronted with broader histories of the environment. The various and even very opposite hypotheses it contains will be differentiated and deepened in the module. In particular that of autonomy will be discuss regarding to the so-called &quot;cession&quot; scenario.</td>
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<td>Objective</td>
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<tr>
<td></td>
<td>This session aims to understand how and to what extent environmental concerns can influence urban and territorial design. From a critical point of view, it also intends to question the notion of transition under the prism of its antecedents in ecological thinking.</td>
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</tbody>
</table>

| 078-0301-00L | Systemic Thinking in the Age of Transition (EPFL)           | O    | 2 credits | 2G   | external organisers    |
|              | Only for MAS in Urban and Territorial Design               |      |          |      |                         |
|              | Abstract                                                   |      |          |      |                         |
|              | Lecturers: E. Cogato-Lanza, A. Pagani, guests. Systems thinking has regained its topicality due to the need to apprehend interdependencies that characterize our inhabited environment. The technicist approach, which had favored complexity without relating it to systems, has given way to interdisciplinary, contextual and holistic frameworks of understanding and action that lead to new prototypes. |
|              | Objective                                                  |      |          |      |                         |
|              | The seminar intends to draw up a cartography of the most current theoretical references and strategic experiments of systemic thinking in the field of the territorial project. The two envisaged formats will associate the series of conferences, bringing together protagonists and researchers, with more strictly seminar sessions with a comparative, inventory or bibliographical tone. |
|              | Content                                                    |      |          |      |                         |
|              | The seminar is structured in four modules: Polemics; Concepts; Representations; Projects. |

---

### Electives

**MAS in Urban and Territorial Design - Key for Type**

<table>
<thead>
<tr>
<th></th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

#### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</tbody>
</table>

**ECTS**

- European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
## MAS Mediation in Peace Processes

### Modules

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>868-0001-00L</td>
<td>Module 1: Mediation in Context</td>
<td>O</td>
<td>10 credits</td>
<td>9G</td>
<td>L.-E. Cederman, to be announced</td>
</tr>
<tr>
<td></td>
<td>Only for MAS Mediation in Peace Processes.</td>
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<tr>
<td>Abstract</td>
<td>This module defines and contextualises peace mediation in relation to other conflict resolution approaches. The module focuses heavily on conflict analysis, introducing the students to the latest knowledge about conflict typologies, trends, and causes in addition to providing them with various opportunities to practice conflict analysis using diverse methods.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>This module defines and contextualises peace mediation in relation to other conflict resolution approaches. The module focuses heavily on conflict analysis, introducing the students to the latest knowledge about conflict typologies, trends, and causes in addition to providing them with various opportunities to practice conflict analysis using diverse methods.</td>
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</tbody>
</table>

| 868-0004-00L | Module 4: Mediation Process Design            | O    | 10 credits | 9G    | L.-E. Cederman                    |
|             | Does not take place this semester.            |      |        |       |                                  |
| Abstract    | Mediators help the parties reach a peace agreement by designing and structuring the process. This module covers the basic elements of process design and how they differ. Important to process design is the reflection on theory and practice in sequencing the content to be examined. The module then explores the implications and challenges facing the implementation of peace agreements for mediators. |
| Objective   | Mediators help the parties reach a peace agreement by designing and structuring the process. This module covers the basic elements of process design and how they differ. Important to process design is the reflection on theory and practice in sequencing the content to be examined. The module then explores the implications and challenges facing the implementation of peace agreements for mediators. |

| 868-0006-00L | Module 6: Mediation Processes                 | O    | 6 credits | 9G    | L.-E. Cederman                    |
|             | Only for MAS Mediation in Peace Processes.    |      |        |       |                                  |
| Abstract    | This module seeks to integrate all the knowledge, skills, and techniques from previous modules in a multi-day mediation simulation based on a real-life mediation case. It focuses on linking theory and practice, communicating with actors in conflict, and transferring the programme’s content to a professional environment. |
| Objective   | This module seeks to integrate all the knowledge, skills, and techniques from Modules 1-5 in a multi-day mediation simulation. The module focuses on how to link theory and practice, how to communicate this to actors in conflict, and how the content of the programme can be transferred into the professional environment of the participants. On a more strategic/political level, this final module allows participants to introduce, discuss – and maybe influence – the future path of the field in the various countries represented and analysed. |

### MAS Mediation in Peace Processes - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

### Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

### ECTS

- European Credit Transfer and Accumulation System
  - Special students and auditors need special permission from the lecturers.
### First Year Examinations: Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0261-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>8</td>
<td>5V+3U</td>
<td>A. Steiger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Differential and integral calculus for functions of one and several variables; vector analysis; ordinary differential equations of first and of higher order; systems of ordinary differential equations; power series. The mathematical methods are applied in a large number of examples from mechanics, physics and other areas which are basic to engineering.</td>
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<tr>
<td>Objective</td>
<td>Introduction to the mathematical foundations of engineering sciences, as far as concerning differential and integral calculus.</td>
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<tr>
<td>Lecture notes</td>
<td>U. Stammbach: Analysis I/II</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites/notice</td>
<td>Exercises and online quizzes are an important aspect of this course. Attempts at solving these problems will be honored with a bonus on the final grade. See &quot;Performance assessment&quot; for more information.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Linear Algebra I</th>
<th>O</th>
<th>3</th>
<th>2V+1U</th>
<th>N. Hungerbühler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Linear algebra is an indispensable tool of engineering mathematics. The course offers an introduction into the theory with many applications. The new notions are practised in the accompanying exercise classes. The course will be continued as Linear algebra II.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of this course, students will be able to recognize linear structures, and to solve corresponding problems in theory and in practice.</td>
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<tr>
<td>Content</td>
<td>Systems of linear equations, Gaussian elimination, solution space, matrices, LR decomposition, Determinants, structure of linear spaces, normed vector spaces, inner products, method of least squares, QR decomposition, introduction to MATLAB, applications</td>
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<tr>
<td>Prerequisites/notice</td>
<td>Active participation in the exercises is part of this course. It is expected, that students submit 3/4 of all exercises for control.</td>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Mechanics 1: Kinematics and Statics</th>
<th>O</th>
<th>5</th>
<th>3V+2U</th>
<th>E. Mazza</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Basics: Position of a material point, velocity, kinematics of rigid bodies, forces, reaction principle, mechanical power Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction</td>
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<tr>
<td>Objective</td>
<td>The understanding of the fundamentals of statics for engineers and their application in simple settings.</td>
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<tr>
<td>Content</td>
<td>Grundlagen: Lage eines materiellen Punktes; Geschwindigkeit; Kinematik starrer Körper, Translation, Rotation, Kreiselung, ebene Bewegung; Kräfte, Reaktionsprinzip, innere und äussere Kräfte, verteilte Flächen- und Raumkräfte; Leistung</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>* K. Meyberg / P. Vachenauer, Höhere Mathematik 1, Springer 2003</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Übungsblöffer</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Engineering Materials and Production I</th>
<th>O</th>
<th>4</th>
<th>4G</th>
<th>K. Wegener</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The lecture covers the structure and the properties of metallic materials. In the focus are the branches: microscopic structure; thermally activated processes; solidification; elastic, plastic deformation, creep. Generally the lecture also refers to manufacturing, to the processing, and application of the concerning materials.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Understanding the basics of metallic materials for engineers who are confronted with material decisions in design and production.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Content</td>
<td>The lecture covers the structure and the properties of metallic materials. In the focus are the branches: microscopic structure as ideal and real structure, alloying, thermally activated processes e.g. diffusion, recovery, recrystallisation, solidification, elastic and plastic deformation and creep. Generally the lecture also refers to manufacturing, to the processing, and application of the concerning materials.</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>yes</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Machine Elements</th>
<th>O</th>
<th>2</th>
<th>1V+1U</th>
<th>M. Meboldt, Q. Lohmeyer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Introduction to machine elements and mechanical systems as basics of product development. Case studies of their application in products and systems.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The students get an overview of the main mechanical components (machine elements) which are used in mechanical engineering. Selected examples will demonstrate how these can be assembled into functional parts and complete systems such as machinery, tools or actuators. At the same time, also the problem of production (production-oriented design) is discussed. In concurrent lectures / exercises &quot;technical drawing and CAD&quot; the design implementation will be practiced.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>The idea of machine elements is complemented by case studies and illustrated.</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites/notice</td>
<td>The lecture slides will be published beforehand on the website of the pdz.</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Chemistry</th>
<th>O</th>
<th>3</th>
<th>2V+1U</th>
<th>A. de Mello, F. Jenny, C. Mondelli, D. J. Norris, S. Stavrakis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This is a general chemistry course aimed at first year undergraduate students in the Department of Mechanical and Process Engineering (D-MAVT) and graduate students in the Department of Architecture (D-ARCH).</td>
<td></td>
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</tr>
</tbody>
</table>

Objective
The aims of the course are as follows:
1) To provide a thorough understanding of the basic principles of chemistry and its application.
2) To develop an understanding of the atomic and molecular nature of matter and of the chemical reactions that describe its transformations.
3) To emphasize areas considered most relevant in an engineering context.

Content
Electronic structure of atoms, chemical bonding, molecular geometry and bonding theories, intermolecular forces, gases, thermodynamics, chemical thermodynamics, chemical kinetics, equilibria, liquids and solutions, acids and bases, redox- and electrochemistry.

Lecture notes
Slides are available prior to every lecture and can be downloaded from Moodle.

Literature
The course is based on "Chemistry The Central Science" by Brown, LeMay, Bursten, Murphy, Woodward, and Stoltzfus. Pearson, 14th Edition in SI units (global edition).

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Type</th>
<th>Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Subject-specific</td>
<td>Concepts and Theories</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>B</td>
<td>Method-specific</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0321-00L</td>
<td>Technical Drawing and CAD</td>
<td>O</td>
<td>4</td>
<td>4G</td>
<td>K. Shea</td>
</tr>
</tbody>
</table>

Abstract

Objective
The lecture and exercises teach the fundamentals of technical drawing and CAD. After taking the course students will be able to create accurate technical drawings of parts and assemblies as well as read them. Students will also be able to create models of parts and assemblies in a 3D, feature-based CAD system. They will understand the links with simulation, product data management (PDM) and additive manufacturing.

Content
Introduction to Engineering Design
Sketching in Engineering Design

Technical Drawing:
- projections and views
- cuts
- notations
- primitives
- ISO norm elements
- dimensioning
- tolerances
- assemblies
- documentation

CAD:
- CAD basics
- CAD modeling methods
- sketch modeling
- modeling operations
- feature-based modeling
- assemblies
- creating 2D drawings from 3D parts
- links to simulation, e.g. kinematics
- links to model variants and Product Data Management (PDM)
- links to additive manufacturing (3D printing)

Lecture notes
Lecture slides and exercise handouts are available on the course Moodle website: https://moodle-app2.let.ethz.ch/course/index.php?categoryid=56
In addition to the lecture material the following books are recommended (only in German):

**TZ**
Technisches Zeichnen: selbstständig lernen und effektiv üben  
Susanna Labisch und Christian Weber  
2008 Vieweg  

**VSM Normen-Auszugs 2010**  
(kann in den Übungen bestellt und gekauft werden)

**CAD**
Marcel Schmid  
CAD mit NX: NX 8  
J.Schlembach Fachverlag  
ISBN: 978-3-935340-72-4

**Prerequisites / notice**
This course is given as a lecture (1h/week) and an exercise (3h/week). Students are split into working groups for the exercises with a maximum of 20 students per group.

**Semester Fee**  
A fee is charged for printed copies of the course handouts.

### First Year Optional Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0501-02L</td>
<td>Mechanics 1: Kinematics and Statics (Colloquium)</td>
<td>Z</td>
<td>0 credits</td>
<td>1K</td>
<td>R. Hopf</td>
</tr>
</tbody>
</table>

#### Abstract
Basics: Position of a material point; velocity; kinematics of rigid bodies; forces, reaction principle, mechanical power  
Statics: Groups of forces, moments, equilibrium of rigid bodies, reactions at supports, parallel forces, center of gravity, statics of systems, principle of virtual power, trusses, frames, forces in beams and cables, friction

#### Objective
The understanding of the fundamentals of Statics for engineers and their application in simple settings.

#### Content
Basics: Position of a material point; velocity; kinematics of rigid bodies; translation, rotation, planar motion; forces, action-reaction principle, internal and external forces, distributed forces; mechanical power.  
Statics: equivalence and reduction of groups of forces; rest and equilibrium; basic theorem of statics; kinematic and static boundary conditions, applications to supports and clamps of rods and beams; procedures for determination of forces at supports and clamps; parallel forces and centre of gravity; statics of systems, solution using basic theorem and using the principle of virtual power, statically indeterminate systems; statically determinate truss structures, ideal truss structures, nodal point equilibrium, methods for truss force determination; friction, static friction, sliding friction, friction at joints and supports, rolling resistance; forces in cables; beam loading, force and moment vector.

#### Lecture notes
Übungsblätter

#### Literature
Sayir, M.B., Dual J., Kaufmann S., Ingenieurmechanik 1: Grundlagen und Statik, Teubner

### 3. Semester

#### Compulsory Courses

#### Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0363-10L</td>
<td>Analysis III</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Iozzi</td>
</tr>
</tbody>
</table>

#### Abstract
Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

#### Objective
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

#### Content
Laplace Transforms:  
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting  
- Transforms of Derivatives and Integrals, ODEs  
- Unit Step Function, t-Shifting  
- Short Impulses, Dirac's Delta Function, Partial Fractions  
- Convolution, Integral Equations  
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:  
- Fourier Series  
- Functions of Any Period p=2L  
- Even and Odd Functions, Half-Range Expansions  
- Forced Oscillations  
- Approximation by Trigonometric Polynomials  
- Fourier Integral  
- Fourier Cosine and Sine Transform

Partial Differential Equations:  
- Basic Concepts  
- Modeling: Vibrating String, Wave Equation  
- Solution by separation of variables; use of Fourier series  
- D'Alembert Solution of Wave Equation, Characteristics  
- Heat Equation: Solution by Fourier Series  
- Heat Equation: Solutions by Fourier Integrals and Transforms  
- Modeling Membrane: Two Dimensional Wave Equation  
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series  
- Solution of PDEs by Laplace Transform

#### Lecture notes
Lecture notes by Prof. Dr. Alessandra Iozzi: [https://polybox.ethz.ch/index.php/s/D3K0TayOXvlpCA](https://polybox.ethz.ch/index.php/s/D3K0TayOXvlpCA)
Introduction to the fundamentals of technical thermodynamics.

Dimensioning I

Objective

Content

Lecture notes

Prerequisites / notice

Domain A - Subject-specific Competencies

Concepts and Theories

Domain B - Method-specific Competencies

Analytical Competencies

Domain C - Social Competencies

Communication

Domain D - Personal Competencies

Adaptability and Flexibility

151-0303-00L

Dimensioning I

Abstract

Objective

Content

Lecture notes

Literature

Thermodynamics I

Abstract

Objective

Literature


Autumn Semester 2021

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### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0033-10L</td>
<td>Physics I</td>
<td>O</td>
<td>6</td>
<td>4V+2U</td>
<td>L. Degiorgi</td>
</tr>
</tbody>
</table>

**Abstract**

This is a two-semester course introducing students into the foundations of Modern Physics. Topics include electricity and magnetism, light, waves, quantum physics, solid state physics, and semiconductors. Selected topics with important applications in industry will also be considered.

**Objective**

The lecture is intended to promote critical, scientific thinking. Key concepts of Physics will be acquired, with a focus on technically relevant applications. At the end of the two semesters, students will have a good overview over the topics of classical and modern Physics.

**Content**

Electric and magnetic fields, current, magnetism, Maxwell's equations, oscillations, waves.

**Lecture notes**

Notes from lectures will be available (in German).

**Literature**

Hans J. Paus, Physik in Experimenten und Beispielen, Carl Hanser Verlag München Wien (textbook for the lecture), ca. 50 Euro.

alternative E-Book:

The Engineering Tools courses are for MAVT Bachelor's degree students only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0021-00L</td>
<td><strong>Engineering Tool: Introduction to MATLAB</strong>&lt;br&gt;The Engineering Tools courses are for MAVT Bachelor's degree students only.</td>
<td>W+</td>
<td>0.4 credits</td>
<td>1K</td>
<td>B. Berisha</td>
</tr>
<tr>
<td>252-0863-00L</td>
<td><strong>Engineering Tool: Advanced Programming with C++</strong>&lt;br&gt;All Engineering Tool courses are for MAVT-Bachelor students only.</td>
<td>W+</td>
<td>0.4 credits</td>
<td>1K</td>
<td>F. O. Friedrich Wicker</td>
</tr>
</tbody>
</table>

Course can only be taken if the programming project is executed and submitted. If no solution to the programming project is submitted, the course is considered failed («no show»).

### 5. Semester

#### Compulsory Courses Examination Block 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0261-00L</td>
<td><strong>Thermodynamics III</strong>&lt;br&gt;Technical applications of engineering thermodynamics. Extension of thermodynamical fundamentals taught in Thermodynamics I and II.</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>R. S. Abhari, A. Steinfeld</td>
</tr>
<tr>
<td>151-0103-00L</td>
<td><strong>Fluid Dynamics II</strong>&lt;br&gt;Two-dimensional irrotational (potential) flows: stream function and potential, singularity method, unsteady flow, aerodynamic concepts. Vorticity dynamics: vorticity and circulation, vorticity equation, vortex theorems of Helmholtz and Kelvin. Compressible flows: isentropic flow along stream tube, normal and oblique shocks, Laval nozzle, Prandtl-Meyer expansion, viscous effects.</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>P. Jenny</td>
</tr>
</tbody>
</table>

Note: previous course title in German until HS18 "Ingenieur-Tool: Numerisches Rechnen".

- es funktionieren alle Versionen
- netzunabhängige Node-Lizenz (z.B. zum Download im ETH IT Shop)
- folgende Toolboxes/Features müssen installiert sein: Simulink (wird für RT1 benutzt), Curve Fitting Toolbox, Optimization Toolbox, Symbolic Toolbox, Global Optimization Toolbox

Installation Matlab:

- mindestens ein Laptop mit installiertem Matlab mitgebracht wird.
- der Kurs findet in einem Hörsaal statt und es stehen keine Rechner zur Verfügung. Es wird empfohlen, dass pro zwei Studierenden mindestens ein Laptop mit installiertem Matlab mitgebracht wird.
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to
Analytical Competencies
2V+2U
not assessed
not assessed
assessed
not assessed
2V+1U
assessed
S. E. Pratsinis
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic
Concepts and Theories
Taught
competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed
Techniques and Technologies
assessed
Domain B - Method-specific Competencies
Analytical Competencies
assessed
Decision-making
assessed
Media and Digital Technologies
not assessed
Problem-solving
assessed
Project Management
not assessed
Domain C - Social Competencies
Communication
not assessed
Cooperation and Teamwork
not assessed
Customer Orientation
not assessed
Leadership and Responsibility
not assessed
Self-presentation and Social Influence
not assessed
Sensitivity to Diversity
not assessed
Negotiation
not assessed
Domain D - Personal Competencies
Adaptability and Flexibility
not assessed
Creative Thinking
not assessed
Critical Thinking
not assessed
Integrity and Work Ethics
not assessed
Self-awareness and Self-reflection
not assessed
Self-direction and Self-management
not assessed
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to
Compressible flows: isentropic flow along stream tube, normal and oblique shocks, Laval nozzle, Prandtl-Meyer expansion, viscous effects.

Abstract
Signals arise in many engineering applications. They contain information about the behavior of physical systems. Systems respond to
Objective
Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.
Content
This course introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data.

Lecture notes
The handouts in English will be available in digital form.

Literature
A list of references is included in the handouts.

Prerequisites / notice
Analysis I/II, Knowledge of Fluid Dynamics I, thermodynamics of ideal gas

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0573-00L</td>
<td>System Modeling</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>L. Guzzella</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to system modeling for control. Generic modeling approaches based on first principles, Lagrangian formalism, energy approaches and experimental data. Model parametrization and parameter estimation. Basic analysis of linear and nonlinear systems.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronic, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>The handouts in English will be available in digital form.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Relevant chapters (corresponding to lecture notes) from the textbook</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number
Title
Type
ECTS
Hours
Lecturers
151-0575-01L System Modeling W 4 credits 2V+2U A. Carron
Signals arise in many engineering applications. They contain information about the behavior of physical systems. Systems respond to
Abstract
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to
Objective
Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.
Content

Literature
Lecture notes available on course website.

Prerequisites / notice
Control Systems I is helpful but not required.

151-0917-00L Mass Transfer W 4 credits 2V+2U S. E. Pratsinis, V. Mavrantzas, C.-J. Shih
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic
Abstract
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic
Objective
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic
Content
Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature

Prerequisites / notice
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

151-0973-00L Introduction into Process Engineering I W 4 credits 2V+2U F. Donat, C. Müller
Two-dimensional irrotational (potential) flows: stream function and potential, complex notation, singularity method, unsteady flow, aerodynamic concepts.

Vorticity dynamics: vorticity and circulation, vorticity equation, vortex theorems of Helmholtz and Kelvin.

Compressible flows: isentropic flow along stream tube, normal and oblique shocks, Laval nozzle, Prandtl-Meyer expansion, viscous effects.

This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic

Two-dimensional irrotational (potential) flows: stream function and potential, complex notation, singularity method, unsteady flow, aerodynamic concepts.

Vorticity dynamics: vorticity and circulation, vorticity equation, vortex theorems of Helmholtz and Kelvin.

Compressible flows: isentropic flow along stream tube, normal and oblique shocks, Laval nozzle, Prandtl-Meyer expansion, viscous effects.
Objective
To expound fundamentals in process engineering

Content
Overview of process engineering, reactions, balances and residence time analysis; overview of the thermal separation processes; equilibria for multiphase systems; introduction into mechanical process engineering and particle technology

Lecture notes
script in German available

151-3207-00L

Abstract
The elective course Lightweight includes numerical methods for the analysis of the load carrying and failure behavior of lightweight structures, as well as construction methods and design principles for lightweight design.

Objective
The goal of this course is to convey substantiated background for the understanding and the design and sizing of modern lightweight structures in mechanical engineering, vehicle and airplane design.

Content
Lightweight design
Thin-walled beams and structures
Instability behavior of thin walled structures
Reinforced shell structures
Load introduction in lightweight structures
Joining technology
Sandwich design

Lecture notes
Script, Handouts, Exercises

227-0076-00L

Abstract
Sinusoidal signals and systems in the time and frequency domain, principle of operation and design of basic analog and digital circuits as well as analog-digital conversion. Basic power electronic circuits, design of magnetic components, electromechanical energy conversion, principle of operation and characteristics of transformers and selected rotating electrical machines.

Objective
see above

Content

Lecture notes

363-0511-00L

Abstract
"Managerial Economics" provides an introduction to the theories and methods from Economics and Management Science to analyze economic decision-making in the context of markets. The course targets students with no prior knowledge in Economics and Management.

Objective
The objective of this course is to provide an introduction to microeconomic thinking. Based on the fundamental principles of economic analysis (optimization and equilibrium), the focus lies on understanding key economic concepts relevant for understanding and analyzing economic behavior of firms and consumers in the context of markets. Market demand and supply are derived from the individual decision-making of economic agents and market outcomes under different assumptions about the market structure and market power (perfect competition, monopoly, oligopoly, game theory) are studied. This introductory course aims at providing essential knowledge from the fields of Economics and Management relevant for economic decision-making in the context of both the private and public sector.

Literature

401-0435-00L

Abstract
The course gives an introduction to the numerical methods for the solution of ordinary and partial differential equations that play a central role in engineering applications. Both basic theoretical concepts and implementation techniques necessary to understand and master the methods will be addressed.

Objective
At the end of the course the students should be able to:
- implement numerical methods for the solution of ODEs (= ordinary differential equations);
- identify features of a PDE (= partial differential equation) based model that are relevant for the selection and performance of a numerical algorithm;
- implement the finite difference, finite element and finite volume method for the solution of simple PDEs using C++;
- read engineering research papers on numerical methods for ODEs or PDEs.

Content
Initial value problems for ODE: review of basic theory for ODEs, Forward and Backward Euler methods, Taylor series methods, Runge-Kutta methods, basic stability and consistency analysis, numerical solution of stiff ODEs.

Two-point boundary value problems: Green's function representation of solutions, Maximum principle, finite difference schemes, stability analysis.

Elliptic equations: Laplace's equation in one and two space dimensions, finite element methods, implementation of finite elements, error analysis.


Hyperbolic equations: Linear advection equation, method of characteristics, upwind schemes and their stability.

Lecture notes
Script will be provided.

Prerequisites / notice
Not for MSc students belonging to D-MTEC!

401-0603-00L

Abstract
The following concepts are covered: probabilities, random variables, probability distributions, joint and conditional probabilities and distributions, law of large numbers, central limit theorem, descriptive statistics, statistical inference, parameter estimation, confidence intervals, statistical tests, two-sample tests, linear regression.

Objective
Knowledge of the basic principles of probability theory and statistics.

Content
Introduction to probability theory and statistics.

Literature

P. Cheridito

### Focus Project

#### Focus Projects in Mechatronics

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>151-0073-10L</td>
<td>Geranos</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>R. Siegwart</td>
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**Abstract**

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).

**Objective**

The various objectives of the Focus Project are:

- Synthesizing and deepening the theoretical knowledge from the basic courses of the 1. - 4. semester
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<td>151-0073-20L</td>
<td>AITHON</td>
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<tbody>
<tr>
<td>151-0073-30L</td>
<td>Guidance, Navigation and Control for Recovery of a Sounding Rocket</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>M. Zeilinger</td>
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**Abstract**

Students develop and build a product from A-Z! They work in teams and independently, learn to structure problems, to identify solutions, system analysis and simulations, as well as presentation and documentation techniques. They build the product with access to a machine shop and state of the art engineering tools (Matlab, Simulink, etc).
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For enrollment, please contact the D-MAVT Student Administration.

Objective

This focus project, you will develop the platform RAPTOR. The acronym stands for “Rapid Aerial Pick and Transfer of Objects by Robots”. Together with your team, you design, build, and test a flying platform that swoops down towards an object to dynamically pick it up, just like an eagle swoops down to pick up its prey.

The flying system will consist of a soft robot gripper attached to a quadcopter or vertical take-off and landing (VTOL) aircraft. The team's design will first be tested in simulation using tools including Matlab, Gazebo, Drake, and the soft robotics simulator SOFA. A testbed made out of a five bar linkage will facilitate the testing of the design and control of the soft gripper. The testbed emulates quadcopter trajectories on a plane. The testbed will validate the robustness of our gripping experiments in simulation. Successful designs and control algorithms will eventually be tested on a dynamically maneuverable aerial vehicle with self-built gripper.

Project Outline:
https://drive.google.com/open?id=1-B3NYD58Wq3afy3gVJa4a8SzgWNbjRk&authuser=rkatzschm%40ethz.ch&usp=drive_fs

Prerequisites / notice
Optional but helpful: Basics of control theory, machine design, and dynamics. Previous exposure to mechatronics or robotic systems will also be helpful.
### Focus Projects in Manufacturing

<table>
<thead>
<tr>
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<th>Hours</th>
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<tr>
<td>151-0075-10L</td>
<td>E-Sling RE</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>K. Wegener</td>
</tr>
<tr>
<td>151-0075-20L</td>
<td>Formula Student</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>D. Mohr</td>
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<tr>
<td>151-0075-30L</td>
<td>Paris Hybrid</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>A. Kunz</td>
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</tbody>
</table>

For MAVT BSc and ITET BSc only.

Prerequisites for the focus projects:
- Basis examination successfully passed
- Block 1 and 2 successfully passed

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**Abstract**

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**Objective**

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## Focus Projects in Energy, Flows and Processes

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<tbody>
<tr>
<td>151-0076-10L</td>
<td>SOWA (Solar Water) – Drinking Water from Saline and Brackish Water Using Solar Energy</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>M. Mazzotti</td>
</tr>
</tbody>
</table>

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## Focus Projects in Biomedical Engineering

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<tbody>
<tr>
<td>151-0077-10L</td>
<td>VIEshunt</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>M. Meboldt</td>
</tr>
</tbody>
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## Focus Projects in Design, Mechanics and Materials

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<tr>
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<tr>
<td>151-0079-10L</td>
<td>HRC3D - High Resolution 3D Printing of Continuous Fiber Reinforced Composites</td>
<td>W</td>
<td>0</td>
<td>15A</td>
<td>P. Ermanni</td>
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151-0079-20L Hybrid Rocket Engine 21
This course is part of a one-year course. The 14 credit points will be issued at the end of FS2022 with new enrolling for the same Focus Project in FS2022.

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151-0079-30L Swissloop
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Courses Eligible for Focus Projects

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<tr>
<td>151-0079-99L</td>
<td>Vacuum Transport Seminar: Insights into Hyperloop</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>D. Kochmann</td>
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</table>

Abstract
The Vacuum Transport Seminar series enters its third round following the successful editions in spring and autumn semesters. It is held online via Zoom and offered internationally across a number of European Universities. The seminar was founded and is held by Swissloop and the EuroTube Foundation, and partnered by other European institutes.
Objective

Students present their work in Hyperloop research. Additionally, industry experts contribute insight talks. The seminar is open to all students, everyone is welcome to join at any of the dates.

About the seminar’s background:

Swissloop, the Hyperloop Team based at ETH Zürich, is pursuing long-term support for research and education in vacuum transport. In addition to the active team constructing and building a Hyperloop pod every year, various research projects at ETH are pursued in cooperation with EuroTube. The EuroTube Foundation accelerates the development of sustainable vacuum transportation technologies to provide publicly accessible research and testing infrastructures for universities and industry.

About Vacuum Transportation:

The demand for air transport has more than doubled in the last 20 years and is growing yearly by about 6.5%. Global demand for cargo and passenger transportation can barely be met today -- let alone in a sustainable manner. Vacuum transport can replace short to medium distance flights and can significantly reduce CO2 emissions. The market of high-speed transportation is a global megatrend set to affect our lives in years to come.

151-0761-00L Practice Course Product Development

Objective

Participants will receive tips, hints and background information from experienced tutors applicable to current projects.

Content

- Project Management
  - Creating a solid project base
  - Project planning and controlling
  - Product validation and testing
  - Problem solving cycle and decision taking transparent for others
- Communication
  - Communication within the team and with coaches
  - Public Relations in a Nutshell
  - How to acquire and manage suppliers and sponsors
  - Transfer of technical drawings to suppliers
  - Technical reports
  - Review presentations
- Handling of and guidance to
  - Expectation management and dealing with conflicts
  - Burnout prevention, time management, work disturbances
  - Safety issues
  - Issues regarding patents

Lecture notes

Lecture notes and documentation will be electronically available.

Prerequisites / notice

- for students only participating in a Focus Project in the same semester
- the exact schedule will be communicated during the course
- it is expected, that every team is visiting each lecture with typically at least 2 team members

151-0763-00L Practice Course to Focus Projects on CAD and CAE Based on Siemens NX

Objective

Participants will receive tips, hints and background information from experienced tutors applicable to current projects.

Content

- CAD with Siemens NX
  - 2 day of intensive training (2x4h, 1x8L)
- CAE mit Siemens NX
  - 2 separate days of intensive training (2x8L)

Lecture notes

Lecture notes and documentation will be electronically available.

Prerequisites / notice

- only for students participating in a Focus Project in the same semester
- use of Siemens NX CAD/CAE in the corresponding Focus Project required

Focus Specialization

Energy, Flows and Processes

Focus Coordinator: Prof. Christoph Müller

In order to achieve the required 20 credit points for the Focus Specialization Energy, Flows and Processes you need to choose at least 2 core courses (W+) and at least 2 of the elective courses (HS/FS), according to the presentation of the Focus Specialisation (see https://ethz.ch/content/dam/ethz/special-interest/mavt/department-dam/studium/bachelor/documents/EFP_Focus.pdf). One course can be selected among all the courses offered by D-MAVT (Bachelors and Masters).

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<tr>
<td>151-0123-00L</td>
<td>Experimental Methods for Engineers</td>
<td>W+</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>T. Rösgen, B. Schuermans, M. Tibbitt</td>
</tr>
</tbody>
</table>

Abstract

The course presents an overview of measurement tasks in engineering environments. Different concepts for the acquisition and processing of typical measurement quantities are introduced. Following an initial class, laboratory exercises from different application areas (especially in thermofluids and process engineering) are attended by students in small groups.

Objective

- Introduction to various aspects of measurement techniques, with particular emphasis on thermo-fluidic applications.
- Understanding of various sensing technologies and analysis procedures.
- Exposure to typical experiments, diagnostics hardware, data acquisition and processing.
- Study of applications in the laboratory.
- Fundamentals of scientific documentation & reporting.
Presentations, handouts and instructions are provided for each experiment.

This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

The students should become familiar with the fundamentals and with application examples of chemically reactive processes in energy conversion (combustion engines in particular) as well as the synthesis of new materials.

The students should become familiar with the fundamentals and with application examples of chemically reactive processes in energy conversion (combustion engines in particular) as well as the synthesis of new materials. The lecture is part of the focus “Energy, Flows & Processes” on the Bachelor level and is recommended as a basis for a future Master in the area of energy. It is also a facultative lecture on Master level in Energy Science and Technology and Process Engineering.


No script available. Instead, material will be provided in lecture slides and the following text book (which can be downloaded for free) will be followed:


Teaching language, assignments and lecture slides in English


This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

At the end of this course, students will be able to:
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

The global energy transition: Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Lecture notes are available.

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Turbulent flow computation and elements of turbulence modelling

- Properties of laminar, transitional and turbulent flows.
- Origin and control of turbulence. Instability and transition.
- Statistical description, averaging, equations for mean and fluctuating quantities, closure problem.
- Scalings, homogeneous isotropic turbulence, energy spectrum.
- Turbulent free shear flows. Jet, wake, mixing layer.
- Wall-bounded turbulent flows.
- Turbulent flow computation and modeling.

Lecture notes are available.

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

Lecture notes are available.
I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel equations
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

VII- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Plasmonic trapping
6) Applications of optical tweezers

Abstract
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Objective
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Content
Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature

Prerequisites / notice
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

151-0973-00L Introduction into Process Engineering I W 4 credits 2V+2U F. Donat, C. Müller

Abstract
Overview of process engineering, reactions, balances and residence time analysis; overview of the thermal separation processes; equilibria for multiphase systems; introduction into mechanical process engineering and particle technology

Objective
To expound fundamentals in process engineering

Content
Overview of process engineering, reactions, balances and residence time analysis; overview of the thermal separation processes; equilibria for multiphase systems; introduction into mechanical process engineering and particle technology

Lecture notes
script in German available

Mechatronics and Robotics
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

### Lectures
- The lecture notes will be available on the course website.

### Prerequisites / notice
- Control Systems I is helpful but not required.

### Domain A - Subject-specific Competencies
- Communication
- Concepts and Theories
- Techniques and Technologies

### Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

### Domain C - Social Competencies
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

### Domain D - Personal Competencies
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

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### Signals and Systems

**Abstract**
Signals arise in most engineering applications. They contain information about the behavior of physical systems. Systems respond to signals and produce other signals. In this course, we explore how signals can be represented and manipulated, and their effects on systems. We further explore how we can discover basic system properties by exciting a system with various types of signals.

**Objective**
Master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercise.

**Content**

**Lecture notes**
Lecture notes available on course website.

**Prerequisites / notice**
Control Systems I is helpful but not required.

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### Theory of Robotics and Mechatronics

**Abstract**
This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Objective**
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Content**
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Lecture notes**
available.

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### Microrobotics

**Abstract**
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

**Objective**
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

**Content**
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

**Lecture notes**
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

**Prerequisites / notice**
The lecture will be taught in English.

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### Microsystems I: Process Technology and Integration

**Abstract**
Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

**Objective**
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps ( = process flow).
### Content
- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

Application of selected technologies will be demonstrated on case studies.

### Lecture notes
- Handouts (available online)

### Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

### Prerequisites / notice
- Prerequisites: Physics I and II

### 151-0640-00L Studies on Mechatronics
- **W 5 credits 11A**
- **Supervisors**

**Abstract**
Overview of Mechatronics topics and study subjects. Identification of minimum 10 pertinent refereed articles or works in the literature in consultation with supervisor or instructor. After 4 weeks, submission of a 2-page proposal outlining the value, state-of-the art and study plan based on these articles. After feedback on the substance and technical writing by the instructor, project commences.

**Objective**
The students are familiar with the challenges of the fascinating and interdisciplinary field of Mechatronics and Microsystems. They are introduced in the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

**Content**
The students work independently on a study of selected topics in the field of Mechatronics or Microsystems. They start with a selection of scientific papers to continue literature research. The results (e.g. state-of-the-art, methods) are evaluated with respect to predefined criteria. Then the results are presented in an oral presentation and summarized in a report, which takes the discussion of the presentation into account.

**Literature**
will be available

### 151-0913-00L Introduction to Photonics
- **W 4 credits 2V+2U**
- **R. Quidant, J. Ortega Arroyo**

**Abstract**
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

**Objective**
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
## I- BASICS OF WAVE THEORY
1) General concepts  
2) Differential wave equation  
3) Wavefront  
4) Plane waves and Fourier decomposition of optical fields  
5) Spherical waves and Huygens-Fresnel principle

## II- ELECTROMAGNETIC WAVES
1) Maxwell equations  
2) Wave equation for EM waves  
3) Dielectric permittivity  
4) Refractive index  
5) Nonlinear optics  
6) Polarisation and polarisation control

## III- PROPAGATION OF LIGHT
1) Waves at an interface  
2) The Fresnel equations  
3) Total internal reflection  
4) Evanescent waves  
5) Dispersion diagram

## IV- INTERFERENCES
1) General considerations  
2) Temporal and spatial coherence  
3) The Young double slit experiment  
4) Diffraction gratings  
5) The Michelson interferometer  
6) Multi-wave interference  
7) Antireflecting coating and interference filters  
8) Optical holography

## V- LIGHT MANIPULATION
1) Optical waveguides  
2) Photonic crystals  
3) Metamaterials and metasurfaces  
4) Optical cavities

## VI- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts  
2) Direct and Fourier imaging  
3) Image formation  
4) Fluorescence microscopy  
5) Scattering-based microscopy  
6) Digital holography  
7) Computational imaging

## VII- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces  
2) Theory of optical trapping  
3) Atom cooling  
4) Optomechanics  
5) Plasmonic trapping  
6) Applications of optical tweezers

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### 227-0113-00L Power Electronics

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>J. W. Kolar</th>
</tr>
</thead>
</table>

**Abstract**
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

**Objective**
Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

**Content**
- Fields of application and application examples of power electronic converters, basic concept of switch-mode voltage and current conversion, pulse-width modulation (PWM); derivation and operating modes (continuous and discontinuous current mode) of DC/DC converter topologies, buck / boost / buck-boost converter; extension to DC/AC conversion using differences of unipolar output voltages varying over time: single-phase diode rectifier; boost-type PWM rectifier featuring sinusoidal input current; tolerance band AC current control and cascaded output voltage control with inner constant switching frequency current control; local and global averaging of switching frequency discontinuous quantities for calculation of component stresses; three-phase AC/DC conversion, center-tap rectifier with impressed output current, thyristor function, thyristor center-tap and full-bridge converter, rectifier and inverter operation, control angle and recovery time, inverter operation limit; basics of inductors and single-phase transformers, design based on scaling laws; Isolated DC/DC converter, flyback and forward converter, single-switch and two-switch circuit; single-phase DC/AC conversion, four-quadrant converter, unipolar and bipolar modulation, fundamental frequency model of AC-side operating behaviour; three-phase DC/AC converter with star-connected three-phase load, zero sequence (common-mode) and current forming differential-mode output voltage components, fundamental frequency modulation and PWM with singe triangular carrier and individual carrier signals of the phases.

**Lecture notes**
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

**Prerequisites / notice**
Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.
Embedded Systems

W  6 credits  4G  L. Thiele, M. Magno

Abstract
An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.

Objective
Understanding specific requirements and problems arising in embedded system applications.

Content
An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.

The focus of this lecture is on the design of embedded systems using formal models and methods as well as computer-based synthesis methods. Besides, the lecture is complemented by laboratory sessions where students learn to program in C, to base their design on the embedded operating system FreeRTOS, and to edit/debug via an integrated development environment.

Specifically the following topics will be covered in the course: Embedded system architectures and components, software-hardware interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.

More information is available at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Lecture notes
The following information will be available: Lecture material, publications, exercise sheets and laboratory documentation at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Prerequisites
Prerequisites: Basic knowledge in computer architectures and programming.
Objective

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) compare and select mechatronic components that optimally fulfill the defined design requirements;
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Lectures will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Prerequisites

The registration is limited to 26 students. Students are expected to have basic control knowledge from previous classes.

Literature


Prerequisites / notice

The registration is limited to 26 students. There are 4 credit points for this lecture. The lecture will be held in English. The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html

Microsystems and Nanoscale Engineering

Focus Coordinator: Prof. Christofer Hierold

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0621-00L</td>
<td>Microsystems I: Process Technology and Integration</td>
<td>W+</td>
<td>6</td>
<td>3V+3U</td>
<td>M. Haluska, C. Hierold</td>
</tr>
</tbody>
</table>

Abstract

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of Microsystems and -devices by a sequence of defined processing steps (process flow).
Objective
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps (process flow).

Content
- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.
- Application of selected technologies will be demonstrated on case studies.

Lecture notes
- Handouts (available online)

Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology
- Hong Xiao: Introduction to Microsystem Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

Prerequisites / notice
- Prerequisites: Physics I and II

<table>
<thead>
<tr>
<th>151-0509-00L</th>
<th>Microscale Acoustofluidics</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>J. Dual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.</td>
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<tr>
<td>Content</td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobots to surface acoustic wave devices</td>
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<tr>
<td>Objective</td>
<td>Understanding acoustophoresis, the design of devices and potential applications</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<tr>
<th>151-0604-00L</th>
<th>Microrobotics</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>B. Nelson, N. Shamsudhin</th>
</tr>
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<tbody>
<tr>
<td>Abstract</td>
<td>Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.</td>
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<tr>
<td>Objective</td>
<td>The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.</td>
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<tr>
<td>Content</td>
<td>Main topics of the course include: - Scaling laws at micro/nano scales - Electrostatics - Electromagnetism - Low Reynolds number flows - Observation tools - Materials and fabrication methods - Applications of biomedical microrobots</td>
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<tr>
<td>Lecture notes</td>
<td>The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The lecture will be taught in English.</td>
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<table>
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<tr>
<th>151-0643-00L</th>
<th>Studies on Micro and Nano Systems</th>
<th>W</th>
<th>5 credits</th>
<th>11A</th>
<th>Supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>This course is not available to incoming exchange students.</td>
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<tr>
<td>Abstract</td>
<td>The students get familiarized with the challenges of the fascinating and interdisciplinary field of Micro- and Nanosystems. They are introduced to the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.</td>
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<tr>
<td>Objective</td>
<td>The students get familiarized with the challenges of the fascinating and interdisciplinary field of Micro- and Nanosystems. They are introduced to the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.</td>
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<tr>
<td>Content</td>
<td>Students work independently on a study of selected topics in the field of Micro- and Nanosystems. They start with a selection of scientific papers, and continue with an independent literature research. The results (e.g. state-of-the-art, methods) are evaluated with respect to predefined criteria. Then the results are presented in an oral presentation and summarized in a report, which takes the discussion of the presentation into account.</td>
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<tr>
<td>Literature</td>
<td>Literature will be provided</td>
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<thead>
<tr>
<th>151-0902-00L</th>
<th>Micro- and Nanoparticle Technology</th>
<th>W</th>
<th>6 credits</th>
<th>2V+2U</th>
<th>S. E. Pratsinis, G. Kelesidis, V. Mavrantzas, K. Wegner</th>
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<tbody>
<tr>
<td>Number of participants is limited to 20. Additional ones could be enrolled by permission of the</td>
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</table>

This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics. It aims to familiarize motivated M/BSc students with some of the basic phenomena of particles at the nanoscale, thereby illustrating the links between physics, chemistry, materials science and hands-on experience. Furthermore, it aims to give an overview of the field with motivating lectures from industry and academia, including the development of technologies and processes based on particle technology with introduction to design methods of mechanical processes, scale-up laws and optimal use of materials and energy. Most importantly, this course aims to develop the creativity and sharpen the communication skills of motivated students through their individual projects, a PERFECT preparation for the M/BSc thesis (e.g., efficient critical literature search, effective oral/written project presentations), the future profession itself and even life, in general, are always there!

The course objectives are best met primarily through the individual student projects which may involve experiments, simulations or critical and quantitative reviews of the literature. Projects are conducted individually under the close supervision of MSc, PhD or post-doctoral students. Therein, a 2-page proposal is submitted within the first two weeks addressing explicitly, at least, 10 well-selected research articles and thoughtful meetings with the project supervisor. The proposal address 3 basic questions: a) how important is the project; b) what has been done already in that field and c) what will be done by the student. Detailed feedback on each proposal is given by the supervisor, assistant and professor two weeks later. Towards the end of the semester, a 10-minute oral presentation is given by the student followed by 10 minutes Q&A. A 10-page final report is submitted by noon of the last day of the semester. The project supervisor will provide guidance throughout the course. Lectures include some of the following:

- Overview & Project Presentation
- Particle Size Distribution
- Particle Diffusion
- Coagulation
- Agglomeration & Coalescence
- Particle Growth by Condensation
- Control of particle size & structure during gas-phase synthesis
- Multi-scale design of aerosol synthesis of particles
- Particle Characterization
- Aerosol manufacture of nanoparticles
- Forces acting on single particles in a flow field
- Fixed and Fluidized Beds
- Separations of Solid-Liquid & Solid-Gas systems
- Emulsions/droplet formation/microfluidics
- Gas Sensors
- Coaching for proposal & report writing as well as oral presentations

**Literature**


**Prerequisites / notice**

FluidMechanik I, Thermodynamik I & II & “clean” 5th semester BSc student standing in D-MAVT (no block 1 or 2 obligations). Students attending this course are expected to allocate sufficient additional time within their weekly schedule to successfully conduct their project. As exceptional effort will be required! Having seen “Chasing Mavericks” (2012) by Apted & Henson, “Unbroken” (2014) by Angelina Jolie and, in particular, “The Salt of the Earth” (2014) by Wim Wenders might be helpful and even motivating. These movies show how methodic effort can bring superior and truly unexpected results (e.g. stay under water for 5 minutes to overcome the fear of riding huge waves or merciless Olympic athlete training that help survive 45 days on a raft in Pacific Ocean followed by 2 years in a Japanese POW camp during WWII).

**151-0911-00L Introduction to Plasmonics**

*W* 4 credits 2V+1U

**D. Norris**

**Abstract**

This course provides fundamental knowledge of surface plasmon polaritons and discusses the applications in plasmonics.

**Objective**

Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

**Content**

- Fundamentals of Plasmonics
  - Basic electromagnetic theory
  - Optical properties of metals
  - Surface plasmon polaritons on surfaces
  - Surface plasmon polariton propagation
  - Localized surface plasmons
- Applications of Plasmonics
  - Waveguides
  - Extraordinary optical transmission
  - Enhanced spectroscopy
  - Sensing
  - Metamaterials

**Lecture notes**

Class notes and handouts

**Literature**


**Prerequisites / notice**

Physics I, Physics II

**151-0913-00L Introduction to Photonics**

*W* 4 credits 2V+2U

**R. Ghaidan, J. Ortega Arroyo**

**Abstract**

This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practice. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.

Content

I- BASICS OF WAVE THEORY
  1) General concepts
  2) Differential wave equation
  3) Wavefront
  4) Plane waves and Fourier decomposition of optical fields
  5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
  1) Maxwell equations
  2) Wave equation for EM waves
  3) Dielectric permittivity
  4) Refractive index
  5) Nonlinear optics
  6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
  1) Waves at an interface
  2) The Fresnel equations
  3) Total internal reflection
  4) Evanescent waves
  5) Dispersion diagram

IV- INTERFERENCES
  1) General considerations
  2) Temporal and spatial coherence
  3) The Young double slit experiment
  4) Diffraction gratings
  5) The Michelson interferometer
  6) Multi-wave interference
  7) Antireflecting coating and interference filters
  8) Optical holography

V- LIGHT MANIPULATION
  1) Optical waveguides
  2) Photonic crystals
  3) Metamaterials and metasurfaces
  4) Optical cavities

VI- INTRODUCTION TO OPTICAL MICROSCOPY
  1) Basic concepts
  2) Direct and Fourier imaging
  3) Image formation
  4) Fluorescence microscopy
  5) Scattering-based microscopy
  6) Digital holography
  7) Computational imaging

VII- OPTICAL FORCES AND OPTICAL TWEEZERS
  1) History of optical forces
  2) Theory of optical trapping
  3) Atom cooling
  4) Optomechanics
  5) Plasmonic trapping
  6) Applications of optical tweezers

Lecture notes
Class notes and handouts

Literature
Optics (Hecht) - Pearson

Prerequisites / notice
Physics I, Physics II

151-0135-00L Manufacturing I
Type: O
ECTS: 4
Hours: 2V+2U
Lecturers: K. Wegener, M. Boccadoro

Abstract

Objective
Deepened discussion on the machining processes and their optimisation. Outlook on additional areas such as NC-Technique, dynamics of processes and machines, chatter as well as process monitoring.

Printing of these lecture notes does not imply that they are the property of the student. For more information, please contact the D-MAVT Student Administration.

Autumn Semester 2021
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Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Domain C - Social Competencies
- Cooperation and Teamwork
- Customer Orientation
- Sensitivity to Diversity

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Literature
A bibliography will be given during the lectures.

Prerequisites / notice
Recommended for all Bachelor-Students in the 5th semester and Master-Students in the 7th semester (MAVT, MTEC).

Language: Help for English speaking students on request as well as english translations of the slides shown.

Prerequisites: Recommendation: Lecture 151-0700-00L Manufacturing elective course in the 4th semester.

W+ 4 credits 2V+1U P. Acél

151-0717-00L
Mechanical Production: Assembly, Joining and Coating Technology
Understanding of the complexity of the assembly process as well as its meaning as success and cost factor. The assembly with the different aspects of adding, moving, adjusting, controlling parts etc. Adding techniques; solvable and unsolvable connections. Assembly plants. Coating techniques and their tasks, in particular corrosion protection.

To understand assembly in its full complexity and its paramount importance regarding cost and financial success. An introduction into a choice of selected joining and coating techniques.

Assembly as combination of several classes of action like, e.g., joining, handling, fine adjustments, etc. Techniques for joining objects temporarily or permanently. Assembly systems.

Coating processes and their specific applications, with particular emphasis on corrosion protection.

Recommended to the focus production engineering.

Majority of lecturers from the industry.

Coating processes and their specific applications, with particular emphasis on corrosion protection.

Materials and process technology in the context of production, assembly, joining, and coating technology.

The course "Machine tool metrology" deals with the principal design of machine tools, their spindles and linear axes, with possible geometric, kinematic, thermal and dynamic errors of machine tools and testing these errors, with the influence of errors on the workpiece (error budgeting), with testing of drives and numerical control, as well as with checking the machine tool capability.
Knowledge of
- principal design of machine tools
- errors of linear and rotational axes and of machine tools
- influence of errors on the workpiece (error budgeting)
- dynamics of mechanical systems
- measurement data acquisition / digital signal analysis
- experimental modal analysis
- geometric, kinematic, thermal, dynamic testing of machine tools
- test uncertainty
- machine tool capability

Objective
Knowledge about the value added process sequence for electronics manufacturing, planning of electric and electronic product as well as
Forming technology represents with its 70% global share in manufactured metal volume with respect to yield and cost, the most important

Content
Methology for production, machine tool metrology
- basics, like principal machine tool design and machine tool coordinate system
- principal design and errors of linear and rotational axes
- error budgeting, influence of machine errors on the workpiece
- geometric and kinematic testing of machine tools
- reversal measurement techniques, multi-dimensional machine tool metrology
- thermal influences on machine tools and testing these influences
- test uncertainty, simulation
- basic concepts of dynamics of mechanical systems and vibration theory
- sensors and excitation systems
- mode fitting, experimental modal analysis
- testing of drives and numerical control
- machine tool capability

Lecture notes
Documents are provided during the course. English handouts available on request.

Prerequisites / notice
Exercises in the laboratories and with the machine tools of the institute for machine tools and manufacturing (IWF) provide the practical
background for this course.

151-0723-00L Manufacturing of Electronic Devices W+ 4 credits 3G A. Kunz, A. Guber, R.-D. Moryson, F. Reichert

Abstract
The lecture follows the value added process sequence of electric and electronic components. It contains: Development of electric and
electronic circuits, design of electronic circuits on printed circuit boards as well as in hybrid technology, integrated test technology, planning
of production lines, production of highly integrated electronic on a wafer as well as recycling.

Objective
Knowledge about the value added process sequence for electronics manufacturing, planning of electric and electronic product as well as
their production, planning of production lines, value added process sequence for photovoltaics.

Content
Nothing works without electronics! Typical products in mechanical engineering such as machine tools, as well as any kind of vehicle
contain a significant amount of electric or electronic components of more than 60%. Thus, it is important to master the value added process
sequence for electric and electronic components.

The lecture starts with a brief introduction of electric and electronic components and the planning of integrated circuits. Next, an overview will be
provided about electronic functional units assembled from these electronic components, on printed circuit boards as well as in hybrid
technology. Value added process steps are shown as well as their quality check and their combination for planning a complete
manufacturing line. The lecture further describes the manufacturing of integrated circuits, starting from the wafer via the structuring and
bonding to the packaging. As an example, the manufacturing of micro-electromechanic and electro-optical systems and actuators is
described. Due to similar processes in the electronic production, the value added process sequence for photovoltaics will described too.

The lecture concludes with an excursion to a large manufacturing company. Here, students can the see the application and realization of
the manufacturing of electric and electronic devices.

Lecture notes
Lecture notes are handed out during the individual lessons (CHF 20.-).

Prerequisites / notice
The lecture partly given by experts from industry.

It is supplemented by an excursion to one of the industry partners.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

151-0731-00L Basic Knowledge of Forming Technology W+ 4 credits 2V+2U P. Hora

Abstract
The fundamentals of forming technology are presented to Mechanical, Production and Material Engineers. The content of the lecture is:
Overview of manufacturing with forming techniques, deformation specific description of material properties and their experimental
measurement, material laws, residual stresses, heat balance, tribological aspects of forming processes, workpiece and tool failure.

Objective
Forming technology represents with its 70% global share in manufactured metal volume with respect to yield and cost, the most important
manufacturing process in metal-working industries. Typical applications of forming technology range from the manufacturing of sheet metal
components in auto bodies to applications in food and pharma packaging, fabrication of implants in medical technologies and to the
fabrication of leads in microelectronic components. This course introduces the fundamentals which are essential to evaluate metal-forming
processes and its industrial applications. This includes, together with the acquirements of the most important forming processes, the
characterization of plastic material behavior and manufacturing limits.

Content
Overview of the most important processes of metal-forming technology and its field of applications, the classification of the plastic metal-
forming behavior, basic principles of plastic-mechanical calculations, metal-forming residual stresses, thermo-mechanical coupling of metal-
forming processes, influence of tribology, Work piece failure through cracking and folding, tool failure through rupture and mechanical wear,
metal-forming tools, sheet forming and massive forming processes, handling systems, metal-forming machinery.

Lecture notes
Ja

151-0833-00L Applied Finite Element Analysis W+ 4 credits 2V+2U B. Berisha, N. Manopulo

Abstract
Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior,
contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating
such problems. The finite element program ABAQUUS is introduced to investigate real engineering problems.
The goal of the lecture is to provide the students with the fundamentals of the non-linear Finite Element Method (FEM). The lecture focuses on the principles of the non-linear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the non-linear Finite-Element-Methods are simulations of:

- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Special attention will be paid to the modeling of the non-linear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model which describes the complex non-linear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUUS will be introduced to investigate real engineering problems.

### Content

- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

### Literature


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**227-0113-00L**  
**Power Electronics**  
W 6 credits 4G  
J. W. Kolar

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<td>Self-direction and Self-management</td>
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### Abstract

Fields of application of power electronic converters; basic concept of switch-mode voltage and current conversion; derivation of circuit structures of non-isolated and isolated DC/DC converters, AC/DC- and DC/AC converter structures; analysis procedure and analysis of the operating behaviour and operating range; design criteria and design of main power components.

### Objective

The objective of this course is to understand the impact of Leadership and to learn based on long-term international leadership experiences.

### Content

- The objective of the course is to understand the impact of Leadership and to learn based on long-term international leadership experiences.
- Very practicable competences and skills needed to be a leader.
- What is leadership in a real world? What are the preconditions of personal leadership? What are the differences between Leadership and Management? What is the price to be payed to be a Leader? What are the core competences of a Leader? How to become an inspiring Leader? How to experience exciting leadership in a thrilled real business world.

### Literature

Not mandatory, but to be recommended: "The Effective Executive" from Peter Drucker, Verlag Vahlen; ISBN 978 3 8006 46715 from 2014.

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Lecture notes
Lecture notes and associated exercises including correct answers, simulation program for interactive self-learning including visualization/animation features.

Prerequisites / notice
Prerequisites: Basic knowledge of electrical engineering / electric circuit analysis and signal theory.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Assessed
Assessed

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Assessed
Not assessed
Not assessed
Assessed
Not assessed

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Not assessed
Not assessed
Not assessed
Not assessed
Not assessed
Not assessed

Domain D - Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management
Not assessed
Not assessed
Not assessed
Not assessed
Not assessed
Not assessed

Engineering for Health
Focus Coordinator: Prof. Bradley Nelson

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<tr>
<th>Number</th>
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<th>ECTS</th>
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<td>151-0509-00L</td>
<td>Microscale Acoustofluidics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Dual</td>
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</table>

Abstract
In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.

Objective
Understanding acoustophoresis, the design of devices and potential applications

Content
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices

Literature

Prerequisites / notice
Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Assessed
Assessed

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
Assessed
Not assessed
Not assessed
Assessed
Not assessed

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
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Self-presentation and Social Influence
Sensitivity to Diversity
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Not assessed
Not assessed
Not assessed
Not assessed
Not assessed

Domain D - Personal Competencies
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management
Assessed
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Not assessed
Not assessed

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<td>151-0524-00L</td>
<td>Continuum Mechanics I</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>E. Mazza, A. E. Ehret</td>
</tr>
</tbody>
</table>

Abstract
The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.

Objective
Basic theories for solving continuum mechanics problems of engineering applications, with particular attention to material models.

Content
Anisotropic elasticity, Linear elastic and linear viscous material behavior, Viscoelasticity, Micro-macro modelling, Laminate theory, Plasticity, Viscoplasticity, Examples of engineering applications, Comparison with experiments.

Lecture notes
Yes

<table>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson, N. Shamsudhin</td>
</tr>
</tbody>
</table>

Abstract
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

Objective
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.

This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to:
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyse linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future

**Prerequisites:**
- Physics I and II

**Literature**
- M. Kalina: Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques. Biomedical Imaging
- S. Kozere, K. P. Prüssmann: Biomedical Imaging
- Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011
### Course: Bioelectronics and Biosensors

**W 6 credits 2V+2U  J. Vörös, M. F. Yanik**

**Abstract**
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Objective**
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

**Content**
L1. Bioelectronics history, its applications and overview of the field
- Voltta and Galvani dispute
- BMI, pacemaker, cochlear implant, retina implant, limb replacement devices
- Fundamentals of biosensing
- Glucomer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

**Literature**
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

**Prerequisites / notice**
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

### Course: Movement and Sport Biomechanics

**W 4 credits 3G  B. Taylor, R. List**

**Abstract**
Learning to view the human body as a (bio-) mechanical system. Making the connections between everyday movements and sports activity with injury, discomfort, prevention and rehabilitation.

**Objective**
Students are able to describe the human body as a mechanical system.

**Content**
Movement- and sports biomechanics deals with the attributes of the human body and their link to mechanics. The course includes topics such as functional anatomy, biomechanics of daily activities (gait, running, etc.) and looks at movement in sport from a mechanical point of view. Furthermore, simple reflections on the loading analysis of joints in various situations are discussed. Additionally, questions covering the statics and dynamics of rigid bodies, and inverse dynamics, relevant to biomechanics are investigated.

### Course: Physical Human Robot Interaction (pHRI)

**W 4 credits 2V+2U  O. Lamberty**

**Abstract**
This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.
Objective

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1. identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2. compare and select mechatronic components that optimally fulfill the defined design requirements;
3. derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4. design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5. characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6. investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

Content

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical-human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes

Will be distributed on Moodle before the lectures.

Literature


Prerequisites

Notice:

The registration is limited to 26 students

There are 4 credit points for this lecture.

The lecture will be held in English.

The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html

376-1714-00L Biocompatible Materials

W 4 credits

V 3V

K. Maniura, M. Rottmar, M. Zenobi-Wong

Abstract

Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective

The course covers the following topics:

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**
Handouts are deposited online (moodle).

**Literature**

(available online via ETH library)

Handouts and references therein.

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### Management, Technology, and Economics

**Focus Coordinators:** Prof. Stefano Brusoni D-MTEC and Dr. Bastian Bergmann D-MTEC

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0445-00L</td>
<td>Production and Operations Management</td>
<td>W+</td>
<td>3 credits</td>
<td>2G</td>
<td>T. Netland</td>
</tr>
</tbody>
</table>

**Abstract**
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

**Objective**
This course provides students a broad theoretical basis for understanding, analyzing, designing, and improving operations. After completing this course:
1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can conduct basic process mapping analysis and elaborate on the limitations of the chosen method.
3. Students can calculate the needed capacity to meet demand.
4. Students can select and use problem-solving tools and methods.
5. Students can select and use the basic tools of lean thinking to improve the productivity of production and service operations.
6. Students can explain how new technologies and servitization affect project and operations management.
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

**Content**
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

POM is concerned with the business processes that transform input into output and deliver products and services to customers. POM is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota, to mention a few (although factory management is important and a big part of POM). Also, finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitalization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance measurement. (3) Operations improvement, including problem-solving and the use of new technologies in POM ("Industry 4.0"/digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

**Literature**
Suggested literature is provided in the syllabus.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0445-02L</td>
<td>Production and Operations Management – Supplement Credit</td>
<td>W+</td>
<td>1 credit</td>
<td>1A</td>
</tr>
</tbody>
</table>

**Abstract**
Extension to course 363-0445-00 Production and Operations Management.

**Objective**
This course strengthens the learning objectives of the POM core course (see separate syllabus). After completing this course, students will:
• students can use lean thinking to improve the productivity of production processes,
• students can conduct fundamental process mapping analyses,
• students can select and implement many lean production techniques,
• students can select and use problem-solving tools and methods, and
• students understand the role of management in manufacturing.

**Content**
The course is an extension to the course 363-0445-00 Production and Operations Management. Participants get an extra deep dive into key concepts of POM.

The lectures in this course are highly interactive. To pass this course, students need to complete a course assignment in pairs. The course assignment consists of two parts: preparations for the lecture and a reflection essay after the lecture.

**Prerequisites / notice**
This course (1ECTS) is offered as an extension to the D-MTEC core course 363-0445-02 Production and Operations Management (3 ECTS). To take this course, you have to follow the core course.

Due to its practical format, this course is limited to ca 30 students. Note that we offer this course primarily for students who need the extra credit (total of 4 ECTS) to complete their study plans. This will typically be students from D-MAVT and, in some cases, exchange students. Students from all other departments (including D-MTEC) are welcome to apply to the lecturer. If capacity, applicants may receive written acceptance by the teaching team to join.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0541-00L</td>
<td>Systems Dynamics and Complexity</td>
<td>W+</td>
<td>3 credits</td>
<td>3G</td>
</tr>
</tbody>
</table>

**Abstract**
Finding solutions: what is complexity, problem solving cycle.

Implementing solutions: project management, critical path method, quality control feedback loop.

Controlling solutions: Vensim software, feedback cycles, control parameters, instabilities, chaos, oscillations and cycles, supply and demand, production functions, investment and consumption.
A successful participant of the course is able to:
- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics

The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics, management (inventory modeling, technology adoption and economics) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These models provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as homework work and tests.

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Lecture notes

<table>
<thead>
<tr>
<th>Course</th>
<th>Systems Dynamics and Complexity (Additional Cases)</th>
<th>1 credit</th>
<th>G. Casiraghi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>363-0541-02L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract

This module is an addition to the course Systems Dynamics and Complexity. It offers additional study cases to MAVT Bachelor students who enroll in the main course.

Objective

MAVT Bachelor students learn how to develop and analyze more sophisticated systems dynamics models from different areas, e.g. from biology (population dynamics, cooperation), management (inventory modeling, technology adoption and economics) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These models provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of complex systems.

Content

1. Modelling path dependence and formation of standards
   - Why do clocks go clockwise? Why do people in most nations drive on the right? Why do nearly all computer keyboards have the QWERTY layout, even though it is more inefficient compared to DVORAK? It turns out that many real-world processes are path dependent, i.e. small random events early in their history determine the ultimate end state, even when all end states are equally likely at the beginning. Students will learn how to model such processes, to understand the feedback mechanisms that lead to path dependence. As a case in point, we will study the ‘war’ between the Betamax and the VHS standards.

2. Optimal migration as promoter of cooperation
   - Mechanisms to promote cooperative behaviour is a vibrant research topic in various fields - economics, evolutionary biology and management science to name but a few. Students will be introduced to one such mechanism - migration. They will develop and analyse a macroscopic model to study how the rate of migration affects the long-term cooperation rate in a population.

3. Information transfer
   - Information flow in a social system (e.g. about the location of resources or appearance of a competitor) is an important component of group living. For example, it is well known that ants can achieve remarkable feats in finding an optimal route to a food patch through pheromone trails. The goal of this study case is to model information transfer in such systems by investigating the dynamics of trail formation in ants. The students will learn that the complexity in navigating to a food source may nevertheless be explained as a simple dynamical system with one control parameter only.

4. Decisions in social societies
   - In many situations individuals have to decide between two or more options. Such decisions often have a profound impact on the system as a whole, especially regarding group cohesion. Group cohesion is preferred, as individuals can benefit from living in groups, yet may not be the underlying reason behind individual choices. In this case, students will develop and extend a macroscopic model of an animal social system faced with a decision to choose a new home, and identify the conditions which promote group cohesion versus group splitting.

5. Antigenic variation of HIV
   - One of the characteristic traits of HIV is that a host can be a carrier and a transmitter of the virus without experiencing symptoms for up to 10 years. This case is concerned with finding the mechanism of HIV disease progression. The students will develop a general population-based model for the interaction of an infectious agent with the host immune system. The model is applicable to a variety of infectious agents, ranging from acute lethal infections to chronic illness. Through analysing and simulating the model, the students will understand how the HIV virus interacts with the host and how the mutation rate of the virus is ultimately responsible for this long asymptomatic period.

6. Compartmental models in epidemiology
   - Many diffusive processes in social systems, such as epidemics, can be understood as a result of the interaction between a few groups (compartments) of individuals. The most common example is to divide a population into those who are susceptible (S) to a disease, those who are infected (I), and those who have recovered (R) and are immune, and to model their interactions. These so called SIR models find widespread application in studying non-biological diffusive processes, e.g. the spread of technological innovations, fads, internet memes etc. In this study case, students will become familiar with the basic components of an SIR model and the conditions under which a disease can cause the outbreak of an epidemic. Students will extend the basic model to investigate more realistic scenarios relevant to e.g. different vaccination strategies.

Lecture notes

Will be provided
B. Clarysse assessed

Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business Analytical Competencies
Communication
Acquaintance with forming processes. Determination of forming processes. Interpretation of forming manufacturing

3G

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
(1) broaden understanding of management principles and frameworks
(2) advance insights into the sources of corporate and entrepreneurial success
(3) develop skills to apply this knowledge to real-life managerial problems

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and / or appreciate the challenges that entrepreneurs and managers deal with.

Content

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple choice exam.

Lecture notes

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

| Objective | Students
| - assess the limits and the potential of corporate sustainability for sustainable development
| - develop critical thinking skills (argumentation, communication, evaluative judgment) that are useful in the context of corporate sustainability using an innovative writing and peer review method.
| - recognize and realize opportunities through team work for corporate sustainability in a business environment
| - present strategic recommendations in teams with different output formats (txt-style debate, consultancy pitch, technology model walk-through, campaign video)
| Literature | Literature recommendations will be distributed during the lecture
| Prerequisites / notice | TEACHING FORMAT/ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.
| Literature | Presentation slides will be made available on moodle prior to lectures.

### 363-0389-00L Technology and Innovation Management

| Content | This course focuses on the analysis of innovation as a pervasive process that cut across organizational and functional boundaries. It looks at the sources of innovation, at the tools and techniques that organizations deploy to routinely innovate, and the strategic implications of technical change.

| Objective | This course intends to enable all students to:
| - understand the core concepts necessary to analyze how innovation happens
| - master the most common methods and tools organizations deploy to innovate
| - develop the ability to critically evaluate the innovation process, and act upon the main obstacles to innovation

### 363-0389-02L Technology and Innovation Management (Additional Cases)

| Prerequisites / notice | Only for Mechanical Engineering BSc.

| Content | This module focuses on the topics that lie at the intersection between management and engineering.

| Objective | Through a project, the students will focus on discussing the business implications of a technology using the tools and theories used in the TIM lecture. This would enable the students to deepen their understanding of managerial issues while focusing on a specific technology. Topics for project work will be proposed in the beginning of the semester.

### 363-0565-00L Principles of Microeconomics

| Content | This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

| Objective | This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer.

Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

### Lecture notes

- The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

- The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2020), Economics, Cengage Learning, Fifth Edition. This book can also be used for the course ‘363-0503-00L Principles of Microeconomics’ (Filipinii).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

### 363-0711-00L Accounting for Managers

**W** 3 credits  2V  J.-P. Chardonnens

**Abstract**

The course Accounting for Managers offers an introduction to financial accounting and management accounting. It provides managers with the necessary knowledge for decision making using accounting information.

**Objective**

By attending this course, students will be able to:
- record business transactions on the different types of accounts.
- establish a balance sheet and an income statement.
- prepare the different financial reports.
- understand the principles of cost accounting.
- determine the cost of production.
- make decisions based on cost information.

**Content**

The first part of the course is devoted to financial accounting. It teaches the principles of double-entre accounting and deals with the recording of commercial transactions on accounts. It describes the work to be carried out at the closing in order to prepare the financial reports according to the generally accepted accounting principles. This type of accounting information is primarily intended for investors and shareholders.

The second part of the course describes the principles of management accounting and explains the different costing methods. It aims to determine the manufacturing cost of production of the different products and services using full and variable costing methods. The accounting information focuses on the internal needs of managers for the purpose of budget preparation and profitability analysis.

**Prerequisites / notice**

This course is a prerequisite for the course Financial Management.

### 363-0790-00L Technology Entrepreneurship

**W** 2 credits  2V  F. Hacklin

**Abstract**

Technology ventures are significantly changing the global economic picture. Technological skills increasingly need to be complemented by entrepreneurial understanding.

This course offers the fundamentals in theory and practice of entrepreneurship in new technology ventures. Main topics covered are success factors in the creation of new firms, including founding, financing and growing a venture.

**Objective**

This course provides theory-grounded knowledge and practice-driven skills for founding, financing, and growing new technology ventures.

A critical understanding of dos and don'ts is provided through highlighting and discussing real life examples and cases.

**Content**

See course website: http://www.entrepreneurship.ethz.ch/education/fall/technology-entrepreneurship.html

**Lecture notes**

Lecture slides and case material

### 363-1082-00L Enabling Entrepreneurship: From Science to Startup

**W** 3 credits  2V  A. Sethi

**Abstract**

Students should provide a brief overview (unto 1 page) of their business ideas that they would like to commercialise through the course. If they do not have an idea, they are required to provide a motivation letter stating why they would like to do this elective. If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

The total number of students will be limited to 40. It is preferable that the students already form teams of at least two persons, where both the team-members would like to do the course. The names of the team-members should be provided together with the business idea or the motivation letter submitted by the students.

The students should submit the necessary information until September 13 and apply to anisethi@ethz.ch

**Objective**

Students have technology competence or an idea that they would like to convert into a startup. They are now in the process of evaluating the steps necessary to do so. In summary:

1. Students want to become entrepreneurs
2. The students can be from business or science & technology
3. The course will enable the students to identify the relevance of their technology or idea from the market relevance perspective and thereby create a business case to take it to market.
4. The students will have exposure to investors and entrepreneurs (with a focus on ETH spin-offs) through the course, to gain insight to commercialise their idea.
The students would cover the following topics, as the build their idea into a business case:

1. Technology excellence: this assumes that the student has achieved a certain degree of competence in the area of technology that he or she expects to bring to the market.
2. Market need and market relevance: The student would then be expected to identify the possible markets that may find the technology of relevance. Market relevance implies the process of identification of how relevant the market perceives the technology, and whether this can sustain over a longer period of time.
3. IP and IP strategy: Intellectual property, whether in the form of a patent or a trade secret, implies the secret ingredient that enables the student to achieve certain results that competitors are unable to copy. This enables the student (and subsequently the startup) to hold on to the market that they create with customers.
4. Team including future capabilities required: a startup requires multiple people with complementary capabilities. They also need to be motivated while at the same time protecting the interests of the startup.
5. Financials: There is a need of funding to achieve milestones. This includes funding for salaries and running of the company.
6. Investors and funding options: There are multiple funding options for a startup. They all come with different advantages and limitations. It's important for a startup to recognise its needs and find the investors that fit these needs and are best aligned with the vision of the founders.
7. Preparation of business case: The students will finally prepare the business case that can help them to articulate the link of the technology with the market need and its willingness to pay.
8. Legal overview, company forms and shareholders' agreements (including pitfalls).

The seminar includes talks from invited investors, entrepreneurs and legal experts regarding the importance of the various elements being covered in content, workshops and teamwork. There is a particular emphasis on market validation on each step of the journey, to ensure relevance.

**Prerequisites / notice**

This course is relevant for those students who aspire to become entrepreneurs.

Students applying for this course are requested to submit a 1 page business idea or, in case they don't have a business idea, a brief motivation letter stating why they would like to do this course.

If you are unsure about the readiness of your idea or technology to be converted into a startup, please drop me a line to schedule a call or meeting to discuss.

**Taught competencies**

| Domain B - Method-specific Competencies | Media and Digital Technologies | not assessed |
| Domain C - Social Competencies          | Project Management             | not assessed |
|                                         | Cooperation and Teamwork       | not assessed |
|                                         | Customer Orientation            | assessed     |
|                                         | Leadership and Responsibility   | not assessed |
| Domain D - Personal Competencies         | Creative Thinking              | assessed     |
|                                         | Critical Thinking               | not assessed |
|                                         | Self-awareness and Self-reflection | not assessed |
|                                         | Self-direction and Self-management | not assessed |

**363-1109-00L Introduction to Microeconomics**

This course is only for students enrolled in a Bachelor's degree programme.

Students enrolled in a Master's degree programme may attend "Principles of Microeconomics" (LE 363-0503-00L) instead.

Note for D-MAVT students: If you have already successfully completed "Principles of Microeconomics" (LE 363-0503-00L), then you will not be permitted to attend it again.

**Abstract**

The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.

**Objective**

Students acquire a deeper understanding of basic microeconomic models.

They acquire the ability to apply these models in the interpretation of real world economic contexts.

Students acquire a reflective and contextual knowledge on how societies use scarce resources to produce goods and services and distribute them among themselves.

**Content**

Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies

**Lecture notes**

Course material in e-learning environment https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

**Literature**


**Prerequisites / notice**

This course "Einführung in die Mikroökonomie" (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 "Principles of Microeconomics" for Master students.
### Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

**Domain D - Personal Competencies**
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

### Design, Mechanics and Materials

**Focus Coordinator:** Prof. Kristina Shea

In order to achieve the required 20 credit points for the Focus Specialization Design, Mechanics and Material you are free to choose any of the courses offered within the focus and are encouraged to select among those recommended. If you wish to take one of the Master level courses, you must get approval from the lecturer.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0364-00L</td>
<td>Lightweight Structures Laboratory</td>
<td>W+</td>
<td>4</td>
<td>5A</td>
<td>M. Zogg, P. Ermanni</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Teams of 2 to 3 students have to design, size, and manufacture a lightweight structure complying with given specifications. An aircraft wing spar prototype as well as later a second improved spar will be tested and assessed regarding to design and to structural mechanical criteria.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>To develop the skills to identify and solve typical problems of the structure mechanics on a real application. Other important aspects are to foster team work and team spirit, to link theoretical knowledge and practice, to gather practical experiences in various fields related to lightweight structures such as design, different CAE-methods and structural testing.</td>
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</tbody>
</table>
| **Content** | The task of each team (typically 2-2 students) is the realization of a reduced-scale aircraft wing spar, a typical load-carrying structure, with selected materials. The teams are free to develop and implement their own ideas. In this context, specified requirements include information about loads, interface to the surrounding structures. The project is structured as described below:  
- Concept development  
- design of the component including FEM simulation and stability checks  
- manufacturing and structural testing of a prototype  
- manufacturing and structural testing of an improved component  
- cost assessment  
- Report  
The project work is supported by selected teaching units. |
| **Lecture notes** | The project work is supported by selected teaching units. |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-3207-00L</td>
<td>Lightweight</td>
<td>W+</td>
<td>4</td>
<td>2V+2U</td>
<td>P. Ermanni</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The elective course Lightweight includes numerical methods for the analysis of the load carrying and failure behavior of lightweight structures, as well as construction methods and design principles for lightweight design.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The goal of this course is to convey substantiated background for the understanding and the design and sizing of modern lightweight structures in mechanical engineering, vehicle and airplane design.</td>
<td></td>
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</tr>
</tbody>
</table>
| **Content** | Lightweight design  
Thin-walled beams and structures  
Instability behavior of thin walled structures  
Reinforced shell structures  
Load introduction in lightweight structures  
Joining technology  
Sandwich design |
| **Lecture notes** | Script, Handouts, Exercises |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-3213-00L</td>
<td>Integrative Ski Building Workshop</td>
<td>W+</td>
<td>4</td>
<td>9P</td>
<td>K. Shea</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>To apply, please send the following information to <a href="mailto:jchapuis@ethz.ch">jchapuis@ethz.ch</a> by 31.08.2021: Letter of Motivation (one page) , CV, Transcript of Records.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>This course introduces students to engineering design and fabrication by building their own skis or snowboard. Theoretical and applied engineering design skills like CAD, analysis and engineering of mechanical properties, 3D printing, laser cutting and practical handcrafting skills are acquired in the course.</td>
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</table>

To gain hands-on experience in design, mechanics and materials. A selection of sustainable materials are also used to introduce students to sustainable design. The built skis/board will be mechanically tested in the lab as well as together out in the field on a ski day and evaluated from various perspectives. Students can keep their personal built skis/boards after the course.
This practical ski/board design and building workshop consists of planning, designing, engineering and building your own alpine ski or snowboard. Students learn and execute all the needed steps in the process, such as engineering design, CAD, material selection, analysis of the mechanical properties of a composite layup, fabrication, routing wood cores, 3D printing of plastic protectors, milling side walls from wood or ABS plastic, laying up the fibers from carbon, glass, basalt or flax, laminating with resins, sanding and finishing, as well as laser engraving and veneer wood inlays.

Willingness to engage in the practical building of your ski/board also beyond the course hours in the evening.

<table>
<thead>
<tr>
<th>151-0509-00L</th>
<th>Microscale Acoustofluidics</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>J. Dual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.</td>
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<tr>
<td>Objective</td>
<td>Understanding acoustophoresis, the design of devices and potential applications</td>
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<tr>
<td>Content</td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concepts and Theories</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td></td>
<td>assessed</td>
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<td></td>
<td>Domain B - Method-specific Competencies</td>
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<tr>
<td></td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<tr>
<td></td>
<td>Project Management</td>
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<tr>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Domain C - Social Competencies</td>
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<tr>
<td></td>
<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td></td>
<td>Negotiation</td>
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<tr>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Domain D - Personal Competencies</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
</tr>
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<td></td>
<td>Integrity and Work Ethics</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
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<td></td>
<td>assessed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>151-0524-00L</th>
<th>Continuum Mechanics I</th>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
<th>E. Mazza, A. E. Ehret</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.</td>
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<tr>
<td>Objective</td>
<td>Basic theories for solving continuum mechanics problems of engineering applications, with particular attention to material models.</td>
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<tr>
<td>Content</td>
<td>Anisotropic elasticity, Linear elastic and linear viscous material behavior, Viscoelasticity, Micro-macro modelling, Laminate theory, Plasticity, Viscoplasticity, Examples of engineering applications, Comparison with experiments.</td>
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<tr>
<td>Literature</td>
<td>yes</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>151-0544-00L</th>
<th>Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis</th>
<th>W</th>
<th>4 credits</th>
<th>3G</th>
<th>E. Hosseini</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.</td>
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<tr>
<td>Objective</td>
<td>The main objectives of this lecture are:</td>
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<td></td>
<td>- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),</td>
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<td>- Understanding the importance of material science and metallurgical considerations in MAM,</td>
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<td>- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,</td>
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<td>- Using different commercial analysis tools (COMSOL, ANSYS, ABAQUSS) for simulation of the MAM process.</td>
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<tr>
<td>Content</td>
<td>- Introduction to MAM (concept, application examples, pros &amp; cons),</td>
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<tr>
<td></td>
<td>- Powder-bed and powder-blown metal additive manufacturing,</td>
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<td>- Thermo-fluid analysis of additive manufacturing,</td>
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<td>- Continuum-based thermal modelling and experimental validation techniques,</td>
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<td>- Residual stress and distortion simulation and verification methods,</td>
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<td>- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),</td>
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<tr>
<td></td>
<td>- Mechanical property prediction for MAM,</td>
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<tr>
<td></td>
<td>- Microstructure and mechanical response of MAM material (steels, Ti6Al4V, Inconel, Al alloys),</td>
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<tr>
<td></td>
<td>- Design for additive manufacturing</td>
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<td></td>
<td>- Artificial intelligence for AM</td>
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<tr>
<td>Literature</td>
<td>No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>A basic knowledge of mechanical analysis, metallurgy, thermodynamics is recommended.</td>
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</tbody>
</table>
Teaching goals:
4G
R. Spolenak
Repetition and advancement of dislocation theory. Mechanical properties of metals: hardening mechanisms, high temperature plasticity.
This course is designed as a two semester class and the topics reflect the contents covered in both semesters.
assessed
assessed
assessed
Materials at Work I
3 credits
2V+1U
R. Spolenak
available on Moodle
Engineering Design Optimization
W
4 credits
4G
K. Shea, T. Stankovic
Number of participants limited to 60.
The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.
Metal I
W
3 credits
2V+1U
R. Spolenak
Repetition and advancement of dislocation theory. Mechanical properties of metals: hardening mechanisms, high temperature plasticity, alloying effects. Case studies in alloying to illustrate the mechanisms.
Dislocation theory:
Properties of dislocations, motion and kinetics of dislocations, dislocation-dislocation and dislocation-boundary interactions, consequences of partial dislocations, sessile dislocations
Hardening theory:
a. solid solution hardening: case studies in copper-nickel and iron-carbon alloys
b. particle hardening: case studies on aluminium-copper alloys
High temperature plasticity:
thermally activated glide
power-law creep
diffusional creep: Coble, Nabarro-Herring
definition mechanism maps
Case studies in turbine blades
superplasticity
alloying effects
Materials at Work I
W
4 credits
4S
R. Spolenak, E. Dufresne, R. Koopmans
This course attempts to prepare the student for a job as a materials engineer in industry. The gap between fundamental materials science and the materials engineering of products should be bridged. The focus lies on the practical application of fundamental knowledge allowing the students to experience application related materials concepts with a strong emphasis on case-study mediated learning.
Critical Thinking
assessed
assessed
assessed
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
Domain D - Personal Competencies
Creative Thinking
Critical Thinking
151-3209-00L
Engineering Design Optimization
Offered for the last time in HS 2021.
Objective
The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.
Content
Lecture notes
available on Moodle
327-0501-00L
Metals I
Offered for the last time in HS 2021.
Objective
The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.
Content
Dislocation theory:
Properties of dislocations, motion and kinetics of dislocations, dislocation-dislocation and dislocation-boundary interactions, consequences of partial dislocations, sessile dislocations
Hardening theory:
a. solid solution hardening: case studies in copper-nickel and iron-carbon alloys
b. particle hardening: case studies on aluminium-copper alloys
High temperature plasticity:
thermally activated glide
power-law creep
diffusional creep: Coble, Nabarro-Herring
definition mechanism maps
Case studies in turbine blades
superplasticity
alloying effects
327-1204-00L
Materials at Work I
Objective
Teaching goals:
to learn how materials are selected for a specific application
to understand how materials around us are produced and manufactured
to understand the value chain from raw material to application
to be exposed to state of the art technologies for processing, joining and shaping
to be exposed to industry related materials issues and the corresponding language (terminology) and skills
to create an impression of how a job in industry "works", to improve the perception of the demands of a job in industry
Content
This course is designed as a two semester class and the topics reflect the contents covered in both semesters.
Lectures and case studies encompass the following topics:
Strategic Materials (where do raw materials come from, who owns them, who owns the IP and can they be substituted)
Materials Selection (what is the optimal material (class) for a specific application)
Materials systems (subdivisions include all classical materials classes)
Processing
Joining (assembly)
Shaping
Materials and process scaling (from nm to m and vice versa, from mg to tons)
Sustainable materials manufacturing (cradle to cradle) Recycling (Energy recovery)
After a general part of materials selection, critical materials and materials and design four parts consisting of polymers, metals, ceramics and coatings will be addressed.
In the fall semester the focus is on the general part, polymers and alloy case studies in metals. The course is accompanied by hands-on analysis projects on everyday materials.
Literature
Serope Kalpakjian, Steven Schmid
ISBN: 978-0131489653
### Engineering Tools

The Engineering Tools courses are for MAVT Bachelor's degree students only.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0015-10L</td>
<td>Engineering Tool: Experimental Modal Analysis</td>
<td></td>
<td>0.4 credits</td>
<td>1K</td>
<td>D. Spescha</td>
</tr>
<tr>
<td></td>
<td>All Engineering Tools courses are for MAVT Bachelor's degree students only.</td>
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<tr>
<td></td>
<td>Number of participants limited to 16.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Measuring and analysis methods for the determination of transfer functions of mechanical structures. Evaluation and preparation of the measured data for visualisation and interpretation of the dynamic behaviour.</td>
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<tr>
<td>Objective</td>
<td>Introduction into the practical application of measuring and analysis methods for determination of transfer functions of mechanical structures. Evaluation and preparation of the measured data</td>
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<tr>
<td>Content</td>
<td>Handling of accelerometers and force transducers, measurement of transfer functions of mechanical structures, determination and visualisation of vibration modes using practical examples, introduction to vibration theory and its fundamental terms.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>German documents are provided during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>In the practical part of the course, the participants will carry out measurements on structures themselves and then analyse them with respect to natural frequencies and vibration modes.</td>
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</table>

| 151-0025-10L | Engineering Tool: Introduction to CAM and Motion Simulation | 0.4 credits | 1K | M. Schmid |
|              | All Engineering Tools courses are for MAVT Bachelor's degree students only. |      |        |       |                  |
| Number of participants limited to 40. |      |        |       |                  |
| Abstract | Introduction of integrated CAD applications CAM (Computer Aided Manufacturing), Motion Simulation (Kinematics) |      |        |       |                  |
| Objective | The participants learn the possibilities of integrated CAD applications. The goal is to understand the procedures and the most important functions of these applications. |      |        |       |                  |
| Content | CAM (Computer Aided Manufacturing): - Introduction to CAM - Practical examples for 3-axle milling machine and Feature Based Machining - Motion Simulation (Kinematics/Dynamics): - Introduction and practical examples |      |        |       |                  |
| Prerequisites / notice | Voraussetzungen: - CAD-Grundkenntnisse in Siemens NX (CAD 1. Semester) - Verwenden Sie zur Durchführung der Übungen wenn möglich Ihr eigenes Laptop. Siemens NX kann im ETH IT-Shop kostenlos bestellt werden. Es stehen einige Rechner zur Verfügung. |      |        |       |                  |

| 151-0027-10L | Engineering Tool: Programming with LabView | 0.4 credits | 1K | L. Prochazka |
|              | All Engineering Tools courses are for MAVT Bachelor's degree students only. |      |        |       |                  |
| Number of participants limited to 16. |      |        |       |                  |
| Abstract | An introduction is given to the LabView programming environment. The basic concepts of "virtual instruments" and data flow programming are presented. Computer-based exercises are solved during class. A simple electronic data acquisition module is used to demonstrate basic concepts of interface management and data acquisition. |      |        |       |                  |
| Objective | Introduction to the LabView programming environment. Understanding of fundamental concepts: virtual instruments, data flow programming, control structures, data types etc. Development of basic programming skills using in-class exercises on computers. |      |        |       |                  |
| Prerequisites / notice | Information: LabVIEW Engineering Tools course in Fall Semester 2021 |      |        |       |                  |
| Notice | Due to the current Corona situation, the Engineering Tools course in LabVIEW programming will take place online in the Fall Semester 2021. Please, consider the following information: |      |        |       |                  |
|           | 1. On Monday (20.9.21), you will receive an invitation for a Zoom conference meeting containing a link, you can join the course on all 3 afternoons. |      |        |       |                  |
|           | 2. Before the course start, every participant has to install the student version of LabVIEW. The Software is available in the IT Shop (ITSM) for free. During the installation, you have to verify that the driver package for National Instruments data acquisition devices (NI DAQmx) is installed properly. Therefore, consult the corresponding installation instructions. The link for document download can be found in the document repository accessible via "myStudies" or "course catalog". |      |        |       |                  |
|           | 3. During the course, we will work with a data acquisition device from National Instruments. The hardware will be distributed to all participants for the duration of the course. Please, collect the material in the IFD secretariat (ML H31, Maria Halbleib) on Monday (20.9.21) between 1:30 pm and 5 pm and on Tuesday (21.9.21) between 9 am and 11:30 am. Also, you will receive a MEMS-Gyro and an exercise book. You have to acknowledge receipt of the hardware with your signature and the device ID (see the number on the packaging) and pay a deposit of CHF 50. The hardware must be returned to the secretariat within few days after the end of the course. Please, return complete and nicely packed. You can keep the exercise book. |      |        |       |                  |
|           | 4. The first exercise requires a start-file (Audio Equalizer Starting Point 2.vi) which can be downloaded from the teaching document repository as well. Furthermore, you need an MP3-player such as a smartphone or a PC with an audio output (3.5mm jack). Depending on where you follow the course headphones are recommended. |      |        |       |                  |

| 151-0030-10L | Engineering Tool: Modelling and Servo Axis Control of Machine Tool Manipulators | 0.4 credits | 1K | O. Zinn |
|              | All Engineering Tools courses are for MAVT Bachelor's degree students only. |      |        |       |                  |
| Number of participants limited to 30. |      |        |       |                  |
Abstract
This course covers model building and the applied stimulation of power-assisted axles on production machinery using MATLAB/Simulink and provides a practical example of how drive parameters may be set up, how through simulation an optimal axis design can be developed and which characteristics of a production machine can be reliably estimated in advance.

Objective
The students are able to model servo axes considering all relevant components and process influences to simulate the achievable productivity.

Content
1. Introduction, complexity levels in model building for production machines.
2. Complexity level 1: Power-assisted axles, transmission systems, general structural model.
3. Complexity level 2: Robotic models, kinematics and dynamics
4. Complexity level 3: Multi-body models and finite element models
5. Regulation of power-assisted axles, cascade regulator and state regulator extensions.
7. Master slave and gantry operations with dispersed servo drive.
8. Simulation examples in MATLAB/Simulink ((Swivel axle, 5-axle milling machine, parallel kinematic milling machine, industrial robots).

Lecture notes
Wird abgegeben
Prerequisites / notice
Prerequisites: Matlab skills; your laptop with Matlab/Simulink may be useful.

151-0032-10L Engineering Tool: Introduction to the Methods of Six Sigma Quality Control and Lean Production
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 36.

Abstract
The course introduces to Six Sigma quality management and quality improvement, which aims to reduce process variation and to sustain process capability. It introduces also to the Lean production principles, aiming to reduce waste within the processes as well as aiming to a customer taked JIT pull-production.

Objective
The participant gets an overview to the Operational Excellence philosophy and the working methods of these two approches. He learns the most important tools and the interaction of these two approaches. Introduction to the theory-specific aspects of Lean.

Content
1. Understanding the changing environment
   - Globalization, customer requirements, production systems
   - Six Sigma quality philosophy
   - Lean Manufacturing and TPS (Toyota Production System)
2. Quality management with Six Sigma
   - What is Six Sigma
   - DMAIC problem solving approach
   - Use of different control charts
   - Evaluate process capability, DPMO, Cp, Cpk, Taguchi
   - Cause-effect diagram
   - Control plan and sustainability, PDCA
3. Introduction to the Lean approach
   - TPS model, Lean goals and principles
   - A3 project management
   - The 9 types of waste
   - Value add and non value add activities
   - The 8 Lean-Tools , whereof 4
   - 5S workplace organization
   - Value stream mapping (exercise), Little's law, process metrics
   - Continuous flow vs batch
   - Pull Principles, Kanban, DR
   - Cell design
   - Linear Programming
4. Lean and Six Sigma in practice
   - How fits Lean and Six Sigma together
   - Continuous Improvement/Kaizen organization
   - Change-Management, risks
   - Inspire OPEX deployment approach

Lecture notes
Notes will be distributet.

Literature
Ohno, Toyota Production System - Beyond Large Scale Production, Productivity Press, New York, 1988
Töpfer, Six Sigma - Konzeption und Erfolgsbeispiele für praktizierte Null-Fehler Qualität, Springer, 2007

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

151-0047-00L Engineering Tool: Agile Product Development
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 12.

Abstract
Agile product development is gaining high interest in many industries. Still, only few hardware developing firms have adopted Agile approaches into their daily development work due to inadequate trainings. Within this course, students will be introduced to the culture and mindset behind Agile by solving a practical development task in a team of 4 students.

Objective
Students shall experience and internalize the key principles and practices of Agile product development.

Content
Introduction to Agile (principles & methods), team-based development task.
The participants will deepen their existing CAD knowledge and learn new PDM knowledge, so that these may be directly applied and used in their projects. This short course is based on the "Systems Engineering" (SE) method, which was developed at the ETH.

Abstract
The course is about a methodical basis of systematic project work, with a focus on demanding interdisciplinary problems. The participants will be shown how to use it appropriately and correctly in their projects. This short course is based on the "Systems Engineering" (SE) method, which was developed at the ETH.

Objective
The goals of this compact course are:
- Goal-oriented identification and perception of relevant problem areas and project goal setting.
- Deduction and development of procedures for a promising project, including systematic planning of the project content.
- Development of work packages including efficient methodology.
- Simple embedding of the projects in the organization, including relationships with buyers, users and securing project participation.

Content
1. Afternoon: CAD refresher and top down modelling
   - Einstieg ins Systems Engineering; Entstehung, Inhalt und Werdegang; Voraussetzungen (anspruchsvolle Fragestellungen, institutionelle Einbettung, Systemdenken und heuristische Prinzipien);
   - Grundstruktur und Inhalt Lebensphasenmodell; Grundstruktur in Inhalt Problemlösungszyklus;
   - Zusammenspiel von Lebensphasenmodell & Problemlösungszyklus in Projekten
2. Nachmittag:
   - Situationsanalyse: Systemanalyse (Systemabgrenzung (gestaltbarer Bereich, relevante Bereiche des Umsystems)), Methoden der Analyse und Modellierung, Umgang mit Vernetzung, Dynamik und Unsicherheit; wichtigste Methoden der IST-Zustands- und Zukunftsanalyse),
   - Zielformulierung (wichtigste Methoden der Zielformulieren),
   - Konzeptsynthese und Konzeptanalyse (u.a. Kreativität; wichtigste Methoden der Synthese und Analyse),
3. Nachmittag:
   - Beurteilung (u.a. Methoden für mehrdimensionale Kriterienvergleich, z.B. Kosten-Wirksamkeits-Analyse); Diskussion von Planungsbeispielen
   - Diskussion von Planungsbeispielen: Analyse des Methodeneinsatzes, Entwickeln alternativer Vorgehensweisen und Auswahl des zweckmässigsten Vorgehens

Lecture notes
Zusammenfassung wird in elektronischer Form abgegeben; Lehrbuch: die Grundlagen sind in einem Lehrbuch beschrieben
Anwendungsbeispiele: 8 konkrete Anwendungen von Systems Engineering sind in einem Case-Book beschrieben

Prerequisites / notice
Zielpublikum: Der Kurs richtet sich insbesondere an Personen, welche anspruchsvolle Projekte initiieren, planen und leiten müssen
Lernmethode: Der Stoff wird mittels kurzer Vorträge vermittelt und an kurzen Fallbeispielen/Laboren vertieft. Zudem sollen die Lehrinhalte durch selbständiges Studium der Lehrmittel vertieft bzw. ergänzt werden.

151-0057-10L Engineering Tool: Systems Engineering for Project Work
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 60.

151-0059-10L Engineering Tool: CAD-Methodology and PDM-Technology in the Focus Project
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 25.

Abstract
The participants learn about the procedures and tools that are necessary to develop technical products. The focus is on computer-based design and development and the management in an integrated software environment.

Objective
The participants will deepen their existing CAD knowledge and learn new PDM knowledge, so that these may be directly applied and used in the focus project.
- CAD refresh (Modelling, Assembling, Drafting, etc.) and CAD mythology for construction (Top-Down modelling)
- Introduction to the Team Center (Siemens PDM System)
- TeamCenter data flow, in particular the process of creating and managing new Items and Parts, the approval procedure and creating different versions of Parts

Content
1. Afternoon: CAD refresher and top down modelling
   - To refresh already existing knowledge of CAD functionality.
   - Sketch and features as well as manipulation and optimizing models.
   - Assembling
   - Drafting
   - Organisation. working methods, conventions.
   - Top down modelling CAD
     i. Introduction to top down modelling and concept modelling
     ii. Case study of top down modelling
2. Afternoon: Introduction to TC (Team Center)
   - Introduction: Short introduction to PLM (What is the idea of PLM? PLM is more than the pure management of drawings!)
   - Lesson 1 - Team Center Rich Client Interface
   - Lesson 2 - TC data types
   - Lesson 3 - Construction from data in TC
   - Lesson 4 - Searching for and examining data.
3. Afternoon: TC application
   - Lesson 5 - Unit lists (PSE)
   - Lesson 6 - Cross-referencing
   - Lesson 7 - Data release
   - Lesson 8 - Product data examination

Prerequisites / notice
- at least two students of a Focus-Team should sign in for this course, if the use of Siemens TeamCenter PLM is given for the Team.
- only for students participating in a Focus Project in the same semester
- not more than 25 students
Vector Graphics
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 80.

Abstract
This course provides insights into the structure and compilation of scientific papers and publications using LaTeX as well as open source software for image editing and the creation of vector graphics. LaTeX is a typesetting tool that separates text format and layout. It is widely used for reports and publications in the scientific domain.

Objective
By looking at specific examples during class you will obtain an overview on composing scientific papers (e.g. bachelor theses, semester theses, master theses) using LaTeX and acquire the most important commands to typeset complex formulas, tables and graphics.

Content
-- layout of scientific reports
-- writing with LaTeX (structure, formatting, formulas, tables, graphics, references, table of contents, hyperlinks, packages) based on a template for bachelor/ semester/ master theses.
-- graphic design and illustration using open source software and Matlab
-- including PDF files in the report (project description, data sheets)
-- managing bibliography databases

Literature
http://www.relab.ethz.ch/education/courses/engineering-tools-latex.html

Prerequisites / notice
The exercises will be done on your personal laptop (at least one laptop per two students). The complete (full) LaTeX package, Inkscape and Gimp should be installed in advance.

151-0062-10L Engineering Tool: Computer-Aided Design Methods
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 25.

Abstract
Participants will learn about the Computer-Aided Design fundamentals and methods that are necessary to model complex technical products. The focus will be placed on feature-based and parametric modelling that is common to all modern CAD tools used in mechanical engineering design.

Objective
CAD knowledge and skills will be further developed to enable students to recognize both the advantages and the limitations of current Computer-Aided Design tools. Examples of how to build feature-based and parametric models including design automation will be given along with common pitfalls. After taking the course students should be able to independently create effective feature-based and parametric models of mechanical parts.

Content
1. CAD Methods and Feature-Based Design (2 afternoons):
   * CAD in the context of the design process
   * Feature types and their relation to mechanical design
   * Strategies for building feature-based assemblies
   * Integration of digital part libraries
   * Common issues and difficulties with feature interaction
2. CAD and Parametric Modeling (1 afternoon):
   * Designing and building parametric models
   * Design automation to create design variants
   * Common issues and difficulties with parametric modelling

Lecture notes available on Moodle

151-0067-10L Engineering Tool: Sketching and Visualization of Technical Concepts
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 20.

Abstract
This course is offered by the Design and Technology Lab Zurich. Effective visualizations of ideas are essential to communicate technical concepts. This course focusses on the basics of a coherent draft design through forms of sketches using various simple techniques.

Objective
Mastering various simple techniques for the visualization of technical ideas.

Content
Basics in: Perspective, line drawing, proportions, implementation of the plan views of perspective

Lecture notes will be distributed

Literature
It requires no further books

Prerequisites / notice
Max 20 participants
Material: Paper and pens

151-0091-10L Engineering Tool: Scientific Writing
All Engineering Tools courses are for MAVT Bachelor's degree students only.

Number of participants limited to 60.

Abstract
Participants acquire scientific writing basics as a core competency to communicate with different audiences. They apply important methods and tools to refine a scientific question, research and evaluate the necessary information, quote and paraphrase, and to plan the structure of their own text.

Objective
Students are able to
- derive and structure ideas for a text starting from a scientific question using simple techniques
- find literature sources, check their relevance and completeness, organize them with a suitable tool and cite correctly
- apply a reading technique for summarizing a text
- distinguish plagiarism, quotation and paraphrase in texts using the presented criteria and correctly cite or paraphrase external content
- use and cite information from the Internet correctly
- plan and structure specialized texts that refer to different target groups
**KURSPROGRAMM**

**LEHRFORMEN**
- Inputs: Kurzvorträge und Selbstlernsequenzen
- Übungen: Hausaufgaben und während des Nachmittags selbständig in Moodle anhand von Fallstudien
- Feedback und Diskussion: Lösungen der Studierenden werden gemeinsam mit den Dozierenden besprochen und diskutiert

Zu allen Inhaltsteilen gibt es Übungsteile in Moodle, für die ein Laptop mit funktionierendem Internetanschluss benötigt wird.

**Prerequisites / notice**

**252-0864-00L Engineering Tool: Parallel and Concurrent Programming in C++**

*Abstract*
This course provides an introduction to parallel and concurrent programming, using C++. Basic challenges and concepts will be introduced and illustrated, and applied by students in small projects.

*Objective*
Students develop a basic understanding of the advantages and pitfalls of concurrency, and gain an overview of the field and its concepts. They learn how to solve small problems using concurrent programs.

*Prerequisites / notice*
The course can only be passed if the projects are executed and submitted. If no or insufficient solutions are submitted, the course is considered failed ("drop out").

**Workshop Training**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0003-00L</td>
<td>Workshop Training</td>
<td>O</td>
<td>5</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

*Abstract*
The main objective of the minimum five-week internship is to provide Bachelor’s students with practical experience in producing components as well as knowledge and understanding about materials and their machining and finishing.

*Objective*
The main objective is to provide Bachelor’s students with practical experience in producing components as well as knowledge and understanding about materials and their machining and finishing.

*Prerequisites / notice*
The minimum duration of the workshop training is five weeks.

**Laboratory Practice**

Students attend at least 10 Laboratory Practices during the 4th and 5th semester. 4 of them must be Physics laboratories. All laboratory works are graded “pass” or “fail”. After completion of 10 laboratory training units, 2 credit points will be issued.

Please register online at www.mavt.ethz.ch/praktika

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0029-10L</td>
<td>Laboratory Practice</td>
<td>O</td>
<td>2</td>
<td>4P</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

*Abstract*
Selected laboratory experiments in physics, mechanical and process engineering. With the Laboratory Training held during the fourth and fifth semester, the students learn how to handle and apply measurement methods and devices. Students are offered a diversified choice of laboratory experiments at least ten of which must be completed. Four of the chosen experiments must be in physics.

*Objective*
With the Laboratory Training held during the fourth and fifth semester, the students learn how to handle and apply measurement methods and devices.

*Prerequisites / notice*
Der Link zur Website, welche alle Informationen für das Physikpraktikum bietet: https://ap.phys.ethz.ch

**GESS Science in Perspective**

see GESS Science in Perspective: Language Courses ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MAVT.

**Bachelor's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0001-10L</td>
<td>Bachelor's Thesis</td>
<td>W</td>
<td>14</td>
<td>30D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

*Abstract*
The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 420 hours and can be done in part- or full-time.

*Objective*
The Bachelor’s Thesis is the culmination of the program. The thesis corresponds to a work load of 420 hours and can be done in part- or full-time. The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem. The topics for the bachelor's thesis are published by the professorship or they can be set in consultation between the professors and the students. Thesis projects in cooperation with the industry are also possible.

*Prerequisites / notice*
The Bachelor's Thesis can only be started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. It is insistently recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved. The declaration of originality is an integral part of the Bachelor's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-3630-00L</td>
<td>Bachelor's Thesis (Focus Spezialization Management, Technology and Economics)</td>
<td>W</td>
<td>14</td>
<td>30D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Supervisor for the Bachelor's Thesis: All D-MTEC

**Autumn Semester 2021**
Abstract
The Bachelor's Thesis is the culmination of the program. The thesis corresponds to a work load of 420 hours and can be done in part- or full-time.

Objective
The students develop, enhance and demonstrate their methodological abilities to independently tackle and solve a given research problem.

Content
The topics for the bachelor's thesis are defined by the professorship or can be set in consultation between the professors and the students.

Prerequisites / notice
The Bachelor's Thesis can be only started when the First Year Examinations, the Additional First Year Courses, the Examination Block 1 and 2 are passed. Exclusively D-MAVT students who have enrolled for the Focus Specialization Management, Technology and Economy are eligible for this type of Bachelor's Thesis.

It is strongly recommended for students to only begin the Bachelor's Thesis if 150 credit points have been achieved.

The declaration of originality is an integral part of the Bachelor's Thesis.

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**Mechanical Engineering Bachelor - Key for Type**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
The courses listed in this category “Core Courses” are recommended. Alternative courses can be chosen in agreement with the tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0105-00L</td>
<td>Quantitative Flow Visualization</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>T. Rösgen</td>
</tr>
<tr>
<td>151-0105-00L</td>
<td>Handouts will be made available.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>The course provides an introduction to digital image analysis in modern flow diagnostics. Different techniques which are discussed include image velocimetry, laser induced fluorescence, liquid crystal thermography and interferometry. The physical foundations and measurement configurations are explained. Image analysis algorithms are presented in detail and programmed during the exercises.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Introduction to modern imaging techniques and post processing algorithms with special emphasis on flow analysis and visualization. Understanding of hardware and software requirements and solutions. Development of basic programming skills for (generic) imaging applications.</td>
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</tr>
<tr>
<td>Content</td>
<td>Frequently used mage processing techniques (filtering, correlation processing, FFTs, color space transforms). Image Velocimetry (tracking, pattern matching, Doppler imaging). Surface pressure and temperature measurements (fluorescent paints, liquid crystal imaging, infrared thermography). Laser induced fluorescence. (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping. Wall shear and heat transfer measurements. Pattern recognition and feature extraction, proper orthogonal decomposition.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts will be made available.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Fluctuodynamics I, Numerical Mathematics, programming skills.</td>
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</tbody>
</table>

| 151-0107-20L | High Performance Computing for Science and Engineering (HPCSE) I | W | 4 | 4G | P. Koumoutsakos, S. M. Martin |
| Abstract | This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering. |
| Objective | The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations. |
| Content | 1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86) |
| Lecture notes | https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/ |
| Literature | • An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann |
| | • Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press |
| | • Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann |
| | • Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press |
| | • Lecture notes |
| Prerequisites / notice | Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. |

| 151-0109-00L | Turbulent Flows | W | 4 | 2V+1U | P. Jenny |
| Abstract | Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling |
| Contents | - Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings, Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows |
| Objective | Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling |
| Lecture notes | Lecture notes are available |

| 151-0125-00L | Hydrodynamics and Cavitation | W | 4 | 3G | C. Bourquard, L. Biasiori-Poulanges |
| Abstract | This course builds on the foundations of fluid dynamics to describe hydrodynamic flows and provides an introduction to cavitation. |
The main learning objectives of this course are:
1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify hydrodynamic instabilities and discuss the stability region.
3. Describe fragmentation of liquids.
4. Explain tension, nucleation, and phase-change in liquids.
5. Describe hydrodynamic cavitation and its consequences in physical terms.
6. Recognise experimental techniques and industrial and medical applications for cavitation.

The course gives an overview on the following topics: hydrostatics, capillarity, hydrodynamic instabilities, fragmentation. Tension in liquids, phase change. Cavitation: single bubbles (nucleation, dynamics, collapse), cavitating flows (attached, cloud, vortex cavitation). Industrial applications and measurement techniques.

Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods will be introduced in this course.

Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

The central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

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The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

The course provides an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

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Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.
The course builds upon three parts:
I. Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II. Theoretical basis of statistical mechanics and kinetic equations.
III. Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   - Particle’s distribution function, Liouville equation, entropy, ensembles; Kinetic theory; Boltzmann equation for rarefied gas, H-theorem, hydromagnetic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation;
   - Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   - Lattice Boltzmann simulations of turbulent flows;
   - Numerical stability and accuracy.

5. Microflow:
   - Rarefraction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   - Relativistic fluid dynamics; flows with phase transitions.

Lecture notes
Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice
The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

151-0215-00L

Abstract
Lecture notes

Objective
This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation.

Content
First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers).

The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures.

Lecture notes
Lecture notes will be distributed during the class.

Literature
Books will be recommended for each chapter.

151-0216-00L

Abstract
This course provides an introduction to acoustics. It focuses on fundamental phenomena of airborne and structure-borne sound waves.

Objective
This lecture combines theoretical principles with practical insights and interpretations.

Content
The lecture combines theoretical principles with practical insights and interpretations.

Lecture notes
Handouts will be distributed during the class.

Literature
Books will be recommended for each chapter.

151-0221-00L

Abstract
The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics.

Objective
The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy.

Content
This course introduces the fundamentals of energy system modeling for the analysis and the optimization of the energy system design and operations.

Objective
At the end of this course, students will be able to:
- define and quantify the key performance indicators of sustainable energy systems;
- select and apply appropriate models for conversion, storage and transport of energy;
- develop mathematical models for the analysis, design and operations of multi-energy systems and solve them with appropriate mathematical tools;
- select and apply methodologies for the uncertainty analysis on energy systems models;
- apply the acquired knowledge to tackle the challenges of the energy transition.

Content
The global energy transition: Key performance indicators of sustainable energy systems; Optimization models; Heat integration and heat exchanger networks; Life-cycle assessment; Models for conversion, storage and transport technologies; Multi-energy systems; Design, operations and analysis of energy systems; Uncertainties in energy system modeling.

Lecture notes
Lecture slides and supplementary documentation will be available online. Reference to appropriate book chapters and scientific papers will be provided.

151-0227-00L

Abstract
In general the course explains the main principles of air transport and elaborates on simple interdisciplinary topics.

Working on broad 14 different topics like aerodynamics, manufacturers, airport operations, business aviation, business models etc. the students get a good overview in air transportation.

The program is taught in English and we provide 11 different experts/lecturers.
Objective
The goal is to understand and explain basics, principles and contexts of the broader air transport industry. Further, we provide the tools for starting a career in the air transport industry. The knowledge may also be used for other modes of transport. Ideal foundation for Aviation II - Management of Air Transport.

Content
Weekly: 1h independent preparation; 2h lectures and 1h training with an expert in the respective field

Concept: This course will be taught as Aviation I. A subsequent course - Aviation II - covers the "Management of Air Transport".

Content: Transport as part of the overall transportation scheme; Aerodynamics; Aircraft (A/C) Designs & Structures; A/C Operations; Aviation Law; Maintenance & Manufacturers; Airport Operations & Planning; Aviation Security; ATC & Airspace; Air Freight; General Aviation; Business Jet Operations; Business models within Airline Industry; Military Aviation.

Technical visit: This course includes a guided tour at Zurich Airport and Dubendorf Airfield (baggage sorting system, apron, Tower & Radar Simulator at Skyguide Dubendorf).

Lecture notes
Preparation materials & slides are provided prior to each class

Literature
Literature will be provided by the lecturers, respectively there will be additional Information upon registration (normally available in Moodle)

Prerequisites / notice
The lecture is planned as class teaching with live‐streaming and recordings.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed
assessed

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
assessed
assessed

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Sensitivity to Diversity
assessed
assessed
assessed

Domain D - Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
assessed
assessed

151-0251-00L Principles, Efficiency Optimization and Future Applications of IC Engines

W 4 credits 2V+1U
Y. M. Wright, P. Soltic

Abstract

Objective
The students get familiar with operating characteristics and efficiency maximization methods of IC engines for propulsion and decentralized electricity (and heat) generation. To this end, they learn about simulation methods and related experimental techniques for performance assessment in a combination of lectures and exercises.

Content
This lecture aims at introducing the students to the working principles and efficiency optimization methods for Internal Combustion (IC) engines which are expected to continue to play a very important role in transportation (long-haul heavy duty, marine) and decentralized combined heat and power generation. Following an overview of different applications and powertrains, the course will focus on the following topics: First, a generic overview of the history of IC-Engines is given, and the basic dimensions and specific engine-relevant terminology are introduced. Next, operating maps for different duty cycles are discussed, highlighting the benefits of individual powertrain configurations for different usage scenarios. The high-pressure thermodynamic process and combustion-induced heat release are analyzed in detail and the design of the combustion processes is discussed in view of further optimization of the energy conversion efficiency. The concept of boosting, its challenges and potential are also presented. In addition, flow field characteristics, convective and radiative heat transfer and combustion modes (Otto, Diesel and “multi-mode” cycles) will be discussed along with possible simulation methods. The course consists of lectures combined with exercises. In addition, several invited guest talks will be held by representatives from Swiss industrial companies active in this field. Provided the pandemic measures allow, visits to different engine test facilities are further envisioned.

Literature

Prerequisites / notice
This course provides background for the course 151-0254-00L "Environmental Aspects of Future Mobility” held in the Spring Semester, where the focus is on emission formation and minimization, exhaust gas after treatment systems and potentials of future synthetic/e-fuels in IC engines; all given in the broader context of a future mobility/transportation options (battery electric, hybrids, fuel cells etc.) and transformation pathways towards sustainability.

151-0368-00L Aeroelasticity

W 4 credits 2V+1U
M. Righi

Abstract
Introduction to the basics and methods of Aeroelasticity. An overview of the main static and dynamic phenomena arising from the interaction between structural and aerodynamic loads.

Objective
The course will provide a basic physical understanding of flow-structure interaction. You will get to know the most important phenomena in the static and dynamic aeroelasticity, as well as a presentation of the most relevant analytical and numerical prediction methods.
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems and discusses their applications in robotics. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

### Content

- Introduction to steady and unsteady thin airfoil theory, extension to three dimension wing aerodynamics, strip theory, overview of numerical methods available (panel methods, CFD).
- Introduction to unsteady aerodynamics (theory): Theodorsen and Wagner functions. Unsteady aerodynamics observed from numerical experiments (CFD). Generalization of simplified mathematical models.
- Presentation of steady aeroelasticity: equations of equilibrium for the typical section, aeroelastic deformation, effectiveness of the aeroelastic system, stability (definition), divergence condition, role played by a control surface, control effectiveness, sweep angle, aeroelastic tailoring of bending-torsion coupling. Ritz model to model beams, use of FEM, modal condensation, choice of generalized coordinates.
- Numerical aeroelasticity (Test Cases extracted from the latest AIAA Aeroelastic Prediction Workshops).
- A script in English language is available.
- Some textbooks related to the material covered in the course:
  - Analytical Competencies
    - W. 2V+1U
  - Robot Dynamics
    - 4 credits
  - Markov-chain Monte Carlo sampling
  - Control-variate and multi-level Monte Carlo estimation
  - All topics are illustrated with engineering applications.

### Literature

- Bisplinghoff Ashley, Aeroelasticity
- Abbott, Theory of Wing sections,
  - D. J. Norris, Stochastic Methods for Engineers and Natural Scientists
  - D. W. Meyer-Massetti, Robot Dynamics
  - M. Hutter, Introduction to Plasmonics
  - A. Bispilnghoff Ashley, Aeroelasticity
fundamentals of plasmonics
- basic electromagnetic theory
- optical properties of metals
- surface plasmon polaritons on surfaces
- surface plasmon polariton propagation
- localized surface plasmons

applications of plasmonics
- waveguides
- extraordinary optical transmission
- enhanced spectroscopy
- sensing
- metamaterials

lecture notes
class notes and handouts

literature
s. a. maier, plasmonics: fundamentals and applications, 2007, springer

prerequisites / notice

151-0917-00l mass transfer

abstract
this course presents the fundamentals of transport phenomena with emphasis on mass transfer. the physical significance of basic principles is elucidated and quantitatively described. furthermore the application of these principles to important engineering problems is demonstrated.

objective
this course presents the fundamentals of transport phenomena with emphasis on mass transfer. the physical significance of basic principles is elucidated and quantitatively described. furthermore the application of these principles to important engineering problems is demonstrated.

content
fick's laws; application and significance of mass transfer; comparison of fick's laws with newton's and fourier's laws; derivation of fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (pr and sc numbers); brownian motion; stokes-einstein equation; mass transfer coefficients (nu and sh numbers); mass transfer across interfaces; analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. applications.

literature

151-0927-00l rate-controlled separations in fine chemistry

abstract
the students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology, and in energy-related applications.

objective
the students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.

content
the class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. examples from both areas illustrate the utility of the methods: 1) adsorption and chromatography; 2) membrane processes; 3) crystallization and precipitation.

literature
recommendations for text books will be covered in the class

prerequisites / notice
requirements (recommended, not mandatory): thermal separation processes i (151-0926-00) and modelling and mathematical methods in process and chemical engineering (151-0940-00)

taught competencies

151-0951-00l process design and safety

abstract
the lecture process design and safety deals with the fundamentals of project management, scale-up, dimensioning and safety of chemical process equipment and plants.

objective
the objective of the lecture is to expound the engineering design approach of important elements in chemical plant design.
Aircraft aerodynamics: Atmosphere; aerodynamic forces (lift, drag); thrust. An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics.

The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented. Representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

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Abstract
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective
This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content
Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

Literature
- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice
For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

636-0507-00L Synthetic Biology II W 8 credits 4A S. Panke, Y. Benenson, J. Stelling

Abstract
Does not take place this semester.
Students in the MSc Biotechnology (Programme Regulations 2017) may select Synthetic Biology II instead of the Research Project I.

7 months biological design project, during which the students are required to give presentations on advanced topics in synthetic biology (specifically genetic circuit design) and then select their own biological system to design. The system is subsequently modeled, analyzed, and experimentally implemented. Results are presented at an international student competition at the MIT (Cambridge).

Objective
The students are supposed to acquire a deep understanding of the process of biological design including model representation of a biological system, its thorough analysis, and the subsequent experimental implementation of the system and the related problems.

Content
Presentations on advanced synthetic biology topics (eg genetic circuit design, adaptation of systems dynamics, analytical concepts, large scale de novo DNA synthesis), project selection, modeling of selected biological system, design space exploration, sensitivity analysis, conversion into DNA sequence, (DNA synthesis external,) implementation and analysis of design, summary of results in form of scientific presentation and poster, presentation of results at the iGEM international student competition (www.igem.org).
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

The aim of the course is to introduce the student to the fundamentals of parallel programming in the context of parallel programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

This course will cover a variety of software and hardware platforms and the associated tools.

The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>Abstract</td>
<td>This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.</td>
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<tr>
<td>Objective</td>
<td>With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.</td>
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<tr>
<td>Content</td>
<td>1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)</td>
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<td>2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)</td>
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<td>3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Block and non-blocking methods, Parallel file I/O, Hybrid programming models</td>
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<td>4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis</td>
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<td>5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods</td>
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<tr>
<td>Lecture notes</td>
<td><a href="https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/">https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/</a></td>
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<tr>
<td>Literature</td>
<td>• An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann</td>
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<td></td>
<td>• Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press</td>
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<td></td>
<td>• Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann</td>
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<td></td>
<td>• Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press</td>
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<td></td>
<td>• Lecture notes</td>
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<td>Prerequisites / notice</td>
<td>Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.</td>
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| 151-0215-00L| Engineering Acoustics I | W | 4 | 3G | N. Noiray, B. Van Damme |
| Abstract | This course provides an introduction to acoustics. It focusses on fundamental phenomena of airborne and structure-borne sound waves. The lecture combines theoretical principles with practical insights and interpretations. |
| Objective | This course is proposed for Master and PhD students interested in getting knowledge in acoustics. Students will be able to understand, describe analytically and interpret sound generation, absorption and propagation. |
| Content | First, magnitudes characterizing sound propagation are reviewed and the constitutive equations for acoustics are derived. Then the different types of sources (monopole/dipole/quadrupole, punctual, non-compact) are introduced and linked to the noise generated by turbulent flows, coherent vortical structures or fluctuating heat release. The scattering of sound by rigid bodies is given in basic configurations. Analytical, experimental and numerical methods used to analyze sound in ducts and rooms are presented (Green functions, Galerkin expansions, Helmholtz solvers). The second part covers elastic wave phenomena, such as dispersion and vibration modes, in infinite and finite structures. |
| Lecture notes | Handouts will be distributed during the class |
| Literature | Books will be recommended for each chapter |

| 151-0317-00L| Visualization, Simulation and Interaction - Virtual Reality II | W | 4 | 3G | A. Kunz |
| Abstract | This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes. |
| Objective | Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems. The goal of the lecture is to provide a deeper knowledge of today’s VE environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given. |
| Content | Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality |
| Lecture notes | The handout is available in German and English. |
| Prerequisites / notice | The handout is available in German and English. |

Didactical concept: The course consists of lectures and exercises.
151-0353-00L  Mechanics of Composite Materials  W  4 credits  2V+1U  P. Ermanni, G. Pappas, M. Sakovsky

Abstract
Focus is on laminated fibre reinforced polymer composites. The courses treats aspects related to micromechanics, elastic behavior of unidirectional and multidirectional laminates, failure and damage analysis, design and analysis of composite structures.

Objective
To introduce the underlying concept of composite materials and give a thorough understanding of the mechanical response of materials and structures made from fibre reinforced polymer composites, including elastic behaviour, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

Content
The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics aspects
- Classical Laminate Theory (CLT)
- Failure hypotheses and damage analysis
- Analysis and design of composite structures
- Variable stiffness structures

Lecture notes
Script, handouts, exercises and additional material are available in PDF-format on the CMASLab webpage resp on moodle.

https://moodle-app2.let.ethz.ch/course/view.php?id=2610

Literature
The lecture material is covered by the script and further literature is referenced in there.

151-0368-00L  Aeroelasticity  W  4 credits  2V+1U  M. Righi

Abstract
Introduction to the basics and methods of Aeroelasticity. An overview of the main static and dynamic phenomena arising from the interaction between structural and aerodynamic loads.

Objective
The course will provide a basic physical understanding of flow-structure interaction. You will get to know the most important phenomena in the static and dynamic aeroelasticity, as well as a presentation of the most relevant analytical and numerical prediction methods.

Content
Introduction to steady and unsteady thin airfoil theory, extension to three dimension wing aerodynamics, strip theory, overview of numerical methods available (panel methods, CFD).

Introduction to unsteady aerodynamics (theory): Theodorsen and Wagner functions. Unsteady aerodynamics observed from numerical experiments (CFD). Generation of simplified mathematical models.

Presentation of steady aeroelasticity: equations of equilibrium for the typical section, aeroelastic deformation, effectiveness of the aeroelastic system, stability (definition), divergence condition, role played by a control surface, control effectiveness, sweep angle, aeroelastic tailoring of bending-torsion coupling. Ritz model to model beams, use of FEM, modal condensation, choice of generalized coordinates.


Numerical aeroelasticity (Test Cases extracted from the latest AIAA Aeroelastic Prediction Workshops).

Aeroelasticity of modern aircraft: assessment of the effects induced by the control surfaces and control systems (Aeroservoelasticity), active controlled aircraft, flutter-suppression systems, certification (EASA, FAA).

Planning and execution of Wind Tunnel experiments with aeroelastic models. Live-execution of an experiment in the WT of the ETH.

Brief presentation of non-linear phenomena like Limit-Cycle Oscillations (LCO)

Lecture notes
A script in English language is available.

Literature
Bispinlinghoff Ashley, Aeroelasticity
Abbott, Theory of Wing sections.
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<td>151-0509-00L</td>
<td>Microscale Acoustofluidics</td>
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<td>J. Dual</td>
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<td><strong>Abstract</strong></td>
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<td>In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to Microsystems and lab on a chip devices.</td>
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<td>Understanding acoustophoresis, the design of devices and potential applications</td>
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<td></td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic micro robotics to surface acoustic wave devices</td>
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<td></td>
<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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<td>Cooperation and Teamwork</td>
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<td>151-0525-00L</td>
<td>Dynamic Behavior of Materials</td>
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<td>4</td>
<td>3G</td>
<td>E. Mazza, A. E. Ehret</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.</td>
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<td>Basic theories for solving continuum mechanics problems of engineering applications, with particular attention to material models.</td>
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<td>Anisotropic elasticity, Linear elastic and linear viscous material behavior, Viscoplasticity, Micro-macro modelling, Laminate theory, Plasticity, Viscoplasticity, Examples of engineering applications, Comparison with experiments.</td>
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<tr>
<td>151-0529-00L</td>
<td>Computational Mechanics II: Nonlinear FEA</td>
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<td>4</td>
<td>3G</td>
<td>L. De Lorenzis</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).</td>
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<td>To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.</td>
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<td><strong>Content</strong></td>
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<td></td>
<td>1. Introduction; various sources of nonlinearities and implications for FEA.</td>
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<td>2. Non-linear kinematics; large deformations, stability problems.</td>
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<td>3. Non-linear material behavior; hyperelasticity, plasticity.</td>
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<td>4. Non-linear boundary conditions; contact problems.</td>
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<td><strong>Lecture notes</strong></td>
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<td>Lecture notes will be provided. However, students are encouraged to take their own notes.</td>
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<td>Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.</td>
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<tr>
<td>151-0532-00L</td>
<td>Nonlinear Dynamics and Chaos I</td>
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<td>G. Haller</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td>The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.</td>
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The lecture introduces optical methods to assess the mechanical behaviour of a structure, of its shape, of material parameters, and to validate results from numerical simulations. Focus is on camera-based techniques for deformation, strain and stress analysis. Applications, strengths and limitations are discussed. The lecture includes two afternoons of hands-on experience at Empa in Dübendorf.

**Objective**
The students are enabled to describe the process of imaging and image acquisition. They know how to design basic experiments based on optical methods. They understand the working principle of the optical techniques for shape, deformation and strain measurement. Most notably, they can explain how a mechanical measurand is transformed into an optical signal such as interference, a change of the polarization state or a change of surface temperature. They know the main application field of the individual techniques. They are able to choose the most appropriate technique for solving a measurement task and to estimate its expected resolution. Through the hands-on experience the students gain a deeper and sustained understanding by applying the theoretical foundations to tangible measurement tasks.

**Content**
After an introduction into optics and image acquisition the lecture explains how to transform mechanical quantities such as shape, deformation, strain or stress into an image content. The measurement techniques make use of a variety of basic principles such as:
- Triangulation
- Interference
- Diffraction
- Birefringence
- Infrared radiation

The techniques are based on cameras, most notably semiconductor sensors as well as micro-bolometers, and make use of incoherent white light and coherent light sources such as lasers.

The topics of the lecture include:
- Optics and imaging
- Digital Image Correlation in 2D and 3D
- Fringe Projection and structured light techniques
- Diffraction and holography
- Speckle pattern interferometry
- Terahertz (THz) techniques
- Thin film measurements
- Photoelasticity
- Thermoelastic Stress Analysis
- Validation of numerical models
- Fibre based methods

We show how the methods can be applied to microsystems as well as large engineering structures. In addition, time-resolved measurements in the context of modal analysis and dynamic events are explained.

The lecture includes two afternoons at Empa, where the student will gain first-hand experience with optical methods in the laboratory. These hands-on classes may include e.g. Digital Image Correlation, speckle pattern interferometry, THz holography, Thermal Stress Analysis, fibre optic sensors, or fringe projection - depending on availability of the equipment and the interest of the students.

**Lecture notes**
Copies of the presented slides will be made available in advance through ILIAS. These slide copies allow the student to add own notes and explanations given during the lecture. We will strive to provide summary scripts for each lesson. Each lecture includes a set of exercises. Standard solutions for the exercises will be posted with a time lag.

Finally, you will be invited to a private blog which shall stimulate the discussion of the lecture content and the exercises.

**Literature**
A good overview on the optical methods is presented in the following text books:


**Prerequisites / notice**
Basic knowledge of optics and interferometry as taught in basic physics courses are advantageous.

We encourage the audience to share their specific questions and measurement tasks.
Adaptive materials offer appealing ways to extend the design space of structures by introducing time-variable properties into them. In this course, the physical working principles of selected adaptive materials are analyzed and simple models for describing their behavior are presented. Some applications are illustrated, also with laboratory experiments where possible.

The study of adaptive materials covers topics that range from chemistry to theoretical mechanics. The aim of this course is to convey knowledge about adaptive materials, their properties and the physical mechanisms that govern their function, so as to develop the skills to deal with this interdisciplinary subject.

This course will provide the students with an insight into the properties and physical phenomena which lead to the features of adaptive materials. Starting from chemomechanical (skeletal muscles), the physical behavior of a wide range of adaptive materials, thermo- and photo-mechanical, electro-mechanical, magneto-mechanical and meta-materials will be thoroughly discussed and analyzed. Up-to-date results on their performance and their implementation in mechanical structures will be detailed and studied in laboratory sessions.

Analytical tools and energy based considerations will provide the students with effective instruments for understanding adaptive materials and assess their performance when integrated in structures or when arranged in particular fashions.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electromechanical coupling (1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electromechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,...

Lecture notes (manuscript and handouts) will be provided

Domain A - Subject-specific Competencies

Concepts and Theories

Analytical Competencies

Problem-solving

Domain B - Method-specific Competencies

Communication

Cooperation and Teamwork

Domain C - Social Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Domain D - Personal Competencies

Self-direction and Self-management

151-0573-00L System Modeling

Introduction to system modeling for control. Generic modeling approaches based on first principles, Lagrangian formalism, energy approaches and experimental data. Model parameterization and parameter estimation. Basic analysis of linear and nonlinear systems.

Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.

This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronic, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,...

The handsout in English will be available in digital form.

A list of references is included in the handouts.

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Project Management

Domain B - Method-specific Competencies

Cooperation and Teamwork

Customer Orientation

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Negotiation

Domain C - Social Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

151-0655-00L Skills for Creativity and Innovation

This lecture aims to enhance the knowledge and competency of students regarding their innovation capability. An overview on predispositions of and different skills for creativity and innovation in individual & team settings is given. The focus of this lecture is clearly on building competencies - not just acquiring knowledge.
Objective
- Basic knowledge about creativity and skills
- Knowledge about individual prerequisites for creativity
- Development of individual skills for creativity
- Knowledge about teams
- Development of team-oriented skills for creativity
- Knowledge and know-how about transfer to idea generation teams

Content
Basic knowledge about creativity and skills:
- Introduction into creativity & innovation: definitions and models

Knowledge about individual prerequisites for creativity:
- Personality, motivation, intelligence

Development of individual skills for creativity:
- Focus on creativity as problem analysis & solving
- Individual skills in theoretical models
- Individual competencies: exercises and reflection

Knowledge about teams:
- Definitions and models
- Roles in innovation processes

Development of team-oriented skills for creativity:
- Idea generation and development in teams
- Cooperation & communication in innovation teams

Knowledge and know-how about transfer to idea generation teams:
- Self-reflection & development planning
- Methods of knowledge transfer

Lecture notes
Slides, script and other documents will be distributed via moodle.ethz.ch
(available only for students registered to this course)

Literature
As well as material handed out in the lecture

151-0703-00L Operational Simulation of Production Lines W 4 credits 2V+1U P. Acél

Abstract
The students learn the application of the event-driven and computer-based simulation for layout and operational improvement of production facilities by means of practical examples. The simulation provides an essential basis for digital twins in Industry 4.0.

Objective
The students learn the right use of (Who? When? How?) of the event-driven and computer-based simulation in the illustration of the operating procedures and the production facilities. The simulation is an important basis for creating a digital twin in the context of Industry 4.0.

Operating simulation in the productions, logistic and scheduling will be shown by means of practical examples. The students should make their first experiences in the use of computer-based simulation.

Content
- Application and application areas of the event-driven simulation
- Simulation in the context of Industry 4.0 (digital twin)
- Exemplary application of a software tool (Technomatrix-Simulation-Software)
- Internal organisation and functionality of simulation tools
- Procedure for application: optimizing, experimental design planning, analysis, data preparation
- Controlling philosophies, emergency concepts, production in sequence, line production, rescheduling
- Application on the facilities projecting

The knowledge is enhanced by practice-oriented exercises and an excursion. A guest speaker will present a practical example.

Lecture notes
Will be sent by email before the lecture (pdf).

Literature
A bibliography will be given during the lectures.

Prerequisites / notice
Recommended for all Bachelor-Students in the 5th semester and Master-Students in the 7th semester (MAVT, MTEC).

151-0705-00L Manufacturing I W 4 credits 2V+2U K. Wegener, M. Boccadoro

Abstract
Deeper insight in manufacturing processes: drilling, milling, grinding, honing, lapping, electro erosion and electrochemical machining.
Stability of processes, process chains and process choice.

Objective
Deepened discussion on the machining processes and their optimisation. Outlook on additional areas such as NC-Technique, dynamics of processes and machines, chatter as well as process monitoring.

Content
Deepened insight in the machining processes and their optimisation, chip removal by undefined cutting edge such as grinding, honing and lapping, machining processes without cutting edges such as EDM, ECM, outlook on additional areas as NC-technique, machine- and process dynamics including chatter and process monitoring

Lecture notes
Yes

Prerequisites / notice
Prerequisites: Recommendation: Lecture 151-0700-00L Manufacturing elective course in the 4th semester.
Language: Help for English speaking students on request as well as English translations of the slides shown.
Abstract
Understanding of the complexity of the assembly process as well as its meaning as success and cost factor. The assembly with the different aspects of adding, moving, adjusting, controlling parts etc., Adding techniques; solvable and unsolvable connections. Assembly plants. Coating techniques and their tasks, in particular corrosion protection.

Objective
To understand assembly in its full complexity and its paramount importance regarding cost and financial success. An introduction into a choice of selected joining and coating techniques.

Content
Assembly as combination of several classes of action like, e.g., joining, handling, fine adjustments, etc. Techniques for joining objects temporarily or permanently. Assembly systems. Coating processes and their specific applications, with particular emphasis on corrosion protection.

Lecture notes
Yes

Prerequisites / notice
Recommended to the focus production engineering. Majority of lecturers from the industry.

Abstract
The course "Machine tool metrology" deals with the principal design of machine tools, their spindles and linear axes, with possible geometric, kinematic, thermal and dynamic errors of machine tools and testing these errors, with the influence of errors on the workpiece (error budgeting), with testing of drives and numerical control, as well as with checking the machine tool capability.

Objective
Knowledge of
- principal design of machine tools
- errors of linear and rotational axes and of machine tools,
- influence of errors on the workpiece (error budgeting)
- dynamics of mechanical systems
- measurement data acquisition / digital signal analysis
- experimental modal analysis
- geometric, kinematic, thermal, dynamic testing of machine tools
- test uncertainty
- machine tool capability

Content
Metrology for production, machine tool metrology
- basics, like principal machine tool design and machine tool coordinate system
- principal design and errors of linear and rotational axes
- error budgeting, influence of machine errors on the workpiece
- geometric and kinematic testing of machine tools
- reversal measurement techniques, multi-dimensional machine tool metrology
- thermal influences on machine tools and testing these influences
- test uncertainty, simulation
- basic concepts of dynamics of mechanical systems and vibration theory
- sensors and excitation systems
- mode fitting, experimental modal analysis
- testing of drives and numerical control
- machine tool capability

Lecture notes
Documents are provided during the course. English handouts available on request.

Prerequisites / notice
Exercises in the laboratories and with the machine tools of the institute for machine tools and manufacturing (IWF) provide the practical background for this course.

Abstract
Control, closed loop control, processing of geometrical data, main drives, noise, flexibility, rationalization and automation, modern machine concepts, thermal and dynamic behavior

Objective
Deeper competence for evaluation and development of production machines, sensitization for unconventional kinematics with their advantages and drawbacks.

Content
Control (PLC, NC), closed loop control, processing of geometrical data, main drives, noise emission, flexibility, rationalization and automation, modern machine concepts like high speed machines, alternative kinematics, ultraprecision machines, thermal and dynamic behavior of machine tools, flexibility, rationalization and automation, practical case studies

Lecture notes
Yes

Prerequisites / notice
Help for English speaking students on request. Parts of the lecture are held in english.

Abstract
The lecture follows the value added process sequence of electric and electronic components. It contains: Development of electric and electronic circuits, design of electronic circuits on printed circuit boards as well as in hybrid technology, Integrated test technology, planning of production lines, production of highly integrated electronic on a wafer as well as recycling.

Objective
Knowledge about the value added process sequence for electronics manufacturing, planning of electric and electronic product as well as their production, planning of production lines, value added process sequence for photovoltaics.

Content
Nothing works without electronics! Typical products in mechanical engineering such as machine tools, as well as any kind of vehicle contain a significant amount of electric or electronic components of more than 60%. Thus, it is important to master the value added process sequence for electric and electronic components.

The lecture starts with a brief introduction of electronic components and the planning of integrated circuits. Next, an overview will be provided about electronic functional units assembled from these electronic components, on printed circuit boards as well as in hybrid technology. Value added process steps are shown as well as their quality check and their combination for planning a complete manufacturing line. The lecture further describes the manufacturing of integrated circuits, starting from the wafer via the structuring and bonding to the packaging. As an example, the manufacturing of micro-electromechanic and electro-optical systems and actuators is described. Due to similar processes in the electronic production, the value added process sequence for photovoltaics will described too.

The lecture concludes with an excursion to a large manufacturing company. Here, students can the see the application and realization of the manufacturing of electronic and electric devices.

Lecture notes
Lecture notes are handed out during the individual lessons (CHF 20.-).

Prerequisites / notice
The lecture is partly given by experts from industry.

It is supplemented by an excursion to one of the industry partners.
The course provides an overview of the mostly used welding technologies and a basic understanding of the technology necessary for planning and realizing welded joints. The students will gain the competence and understanding to select welding processes properly, to specify the seam preparation, and to predict the achievable welding results. The course will be distributed along with the course progress together with the lecture slides.

The course is oriented towards the requirements of IHW / SVS and is part of the program to attain the international welding engineer diploma (IWE).

The lecture teaches on the basic knowledge of major processes in sheet metal, tube and bulk metal forming technologies. In particular, it focuses on the fundamentals of forming processes, including the basics of welding the special properties of the different process technologies and explains the energy sources and the interaction between the process energy and the material discussed. The metallurgical basics to answer material problems are presented. From this process parameters can then be derived to achieve the desired seam qualities.

The course provides a survey over the mostly used welding technologies and a basic understanding of the technology necessary for planning and realizing welded joints. The students will gain the competence and understanding to select welding processes properly, to specify the seam preparation and to predict the achievable welding results. The course will be distributed accompanying the course progress together with the lecture slides.

Content
The study of metal working processes: sheet metal forming, folding die cutting, cold bulk metal forming, ro extrusion, plunging, open die forging, drop forging, milling; active principle; elementary methods to estimate stress and strain; fundamentals of process design; manufacturing limits and machining accuracy; tools and operation; machinery and machine usage.

Lecture notes
ja

151-0833-00L
Applied Finite Element Analysis
W 4 credits 2V+2U
B. Berisha, N. Manopulo

Abstract
Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating such problems. The finite element program ABAQUS is introduced to investigate real engineering problems.

Objective
The goal of the lecture is to provide the students with the fundamentals of the non linear Finite Element Method (FEM). The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the nonlinear Finite-Element-Methods are simulations of:
- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes
Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model which describes the complex non linear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems

Content
- introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

Literature
Lecture slides

151-0917-00L
Mass Transfer
W 4 credits 2V+2U
S. E. Pratsinis, V. Mavrantzas, C.-J. Shih

Abstract
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Objective
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Content
Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature

Prerequisites / notice
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

101-0121-00L
Fatigue and Fracture in Materials and Structures
W 4 credits 3G
E. Ghafoori, A. Taras

Abstract
The fundamentals in fatigue and fracture mechanics, which are used in different engineering disciplines (e.g., for mechanical, aerospace, civil and material engineers) will be discussed. The focus will be on fundamental theories (based on fracture mechanics) that model fatigue damage and crack propagation.

Objective
In this course, the students will learn:
- Linear elastic and elastic-plastic fracture mechanics.
- Modern computer-based techniques (using ABAQUS Finite Element Package) to simulate cracks in both bulk materials and bonded joints/interfaces.
- Laboratory fatigue and fracture tests on details with cracks.
The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered in this course are:

I) Fatigue of materials:
- Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
- Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner's damage rule.
- Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

II) Fracture mechanics:
- Elastostatic fracture mechanics (LEFM): limits of LEFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
- Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
- Fatigue crack growth (FCG): FCG models, Paris' law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

III) Introduction to cohesive zone models (CZMs):
- Advantages and disadvantages of CZMs compared to fracture mechanics.
- Different bond-slip models for the bonded joints/interfaces.

IV) Computer laboratory to simulate cracks and debonding problems:
- Finite Element (FE) modeling of complex details with cracks.
- FE simulations of debonding problems using CZMs.
- Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

V) Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

VI) Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and "Laboratory Competition". The students will:
- Visit different small-scale and large-scale fatigue testing equipment.
- Get to know different ongoing fatigue- and fracture-related projects.
- Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
- Compare the experimental results with their own calculations (from the fracture theories).
- "Laboratory Competition" at Empa: the students with the closest predictions will win the "Empa Laboratory Competition" and will be awarded a prize.

Lecture notes
Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.

Literature

Prerequisites
Note 1: A basic knowledge on mechanics of structures and structural analysis (i.e., stress-strain analysis and calculations of internal deformations, strains and stresses within structures) is recommended and will be helpful in the course.

Note 2: Laboratory demonstrations and fatigue/fracture tests at the Structural Engineering Research Laboratory of Empa in Dübendorf. This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

227-0447-00L Image Analysis and Computer Vision W 6 credits 3V+1U L. Van Gool, E. Konukoglu, F. Yu

Abstract
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0523-00L Railway Systems I W 6 credits 4G M. Meyer

Abstract
- Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
  - Transportation tasks and vehicle types
  - Running dynamics
  - Mechanical part of rail vehicles
  - Brakes
  - Traction chain and auxiliary supply
  - Railway power supply
  - Signalling systems
  - Standards
  - Availability and safety
  - Traffic control and maintenance
Objective
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

Content
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1 Einführung:
1.1 Geschichte und Struktur des Bahnsystems
1.2 Fahrdynamik

2 Vollbahnfahrzeuge:
2.3 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
2.2 Bremsen
2.3 Traktionsantriebssysteme
2.4 Hilfsbetriebe und Komfortanlagen
2.5 Steuerung und Regelung

3 Infrastruktur:
3.1 Fahrdienste
3.2 Bahnstromversorgung
3.3 Sicherungsanlagen

4 Betrieb:
4.1 Interoperabilität, Normen und Zulassung
4.2 RAMS, LCC
4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Geplante Exkursionen:
Betriebszentrale SBB, Zürich Flughafen
Reparatur und Unterhalt, SBB Zürich Altstetten
Fahrzeugzubehör, Stadler Bussnang

Lecture notes
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

Prerequisites / notice
Dozent: Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahnnahstruktur.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |

252-0535-00L Advanced Machine Learning

W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensible to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.
**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

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**252-0543-01L  Computer Graphics**

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<th>W</th>
<th>8 credits</th>
<th>3V+2U+2A</th>
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**Abstract**

This course covers some of the fundamental concepts of computer graphics: generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.

**Objective**

At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students' curiosity to explore the field of computer graphics in subsequent courses or on their own.

**Content**

This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

**Lecture notes**

No

**Literature**

Books:

- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple View Geometry in Computer Vision
- Physically Based Rendering: From Theory to Implementation

**Prerequisites / notice**

**Prerequisites:**

Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++, Visual Computing course recommended.

The programming assignments will be in C++. This will not be taught in the class.

---

**252-0834-00L  Information Systems for Engineers**

<table>
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<tr>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
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**Abstract**

This course provides the basics of relational databases from the perspective of the user. We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

**Objective**

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.

2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).

3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.

4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality

5. Explain what bad design is and why it matters.

6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".

7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.

8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.

9. Explain what data independence is all about and didn't age a bit since the 1970s.

10. Explain, in the big picture, how a relational database is physically implemented.

11. Know and deal with the natural syntax for relational data, CSV.

12. Explain the data cube model including slicing and dicing.

13. Store data cubes in a relational database.

14. Map cube queries to SQL.

15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.
Content

Using a relational database

=============
1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

=============
6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

=============
12. Data cubes

Outlook

=============
13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logics
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python
This course provides students a broad theoretical basis for understanding, analyzing, designing, and improving operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can conduct basic process mapping analysis and elaborate on the limitations of the chosen method.
3. Students can calculate the needed capacity to meet demand.
4. Students can select and use problem-solving tools and methods.
5. Students can select and use the basic tools of lean thinking to improve the productivity of production and service operations.
6. Students can explain how new technologies and servitization affect production and operations management.
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

POM is concerned with the business processes that transform input into output and deliver products and services to customers. POM is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota, to mention a few (although factory management is important and a big part of POM). Also, finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitalization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance measurement. (3) Operations improvement, including problem-solving and the use of new technologies in POM ("Industry 4.0" / digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

Suggested literature is provided in the syllabus.

**Abstract**
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

**Objective**
This course provides students a broad theoretical basis for understanding, analyzing, designing, and improving operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy.
2. Students can conduct basic process mapping analysis and elaborate on the limitations of the chosen method.
3. Students can calculate the needed capacity to meet demand.
4. Students can select and use problem-solving tools and methods.
5. Students can select and use the basic tools of lean thinking to improve the productivity of production and service operations.
6. Students can explain how new technologies and servitization affect production and operations management.
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

**Content**
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

POM is concerned with the business processes that transform input into output and deliver products and services to customers. POM is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota, to mention a few (although factory management is important and a big part of POM). Also, finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitalization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance measurement. (3) Operations improvement, including problem-solving and the use of new technologies in POM ("Industry 4.0" / digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

Suggested literature is provided in the syllabus.

**363-0445-02L Production and Operations Management – W 1 credit 1A T. Netland**

**Supplement Credit**

A parallel enrolment to the lecture 363-0445-00L Production and Operations Management is mandatory.

**Objective**
This course strengthens the learning objectives of the POM core course (see separate syllabus). After completing this course, students can:

- use lean thinking to improve the productivity of production processes,
- conduct fundamental process mapping analysis,
- select and implement many lean production techniques,
- select and use problem-solving tools and methods, and
- understand the role of management in manufacturing.

The lectures in this course are highly interactive. To pass this course, students need to complete a course assignment in pairs. The course assignment consists of two parts: preparation for the lecture and a reflection essay after the lecture.

This course (1ECTS) is offered as an extension to the D-MTEC core course 363-0445-02 Production and Operations Management (3 ECTS). To take this course, you have to follow the core course.

Due to its practical format, this course is limited to ca 30 students. Note that we offer this course primarily for students who need the extra credit (total of 4 ECTS) to complete their study plans. This will typically be students from D-MAVT and, in some cases, exchange students. Students from all other departments (including D-MTEC) are welcome to apply to the lecturer. If capacity, applicants may receive written acceptance by the teaching team to join.

**363-0541-00L Systems Dynamics and Complexity W 3 credits 3G F. Schweitzer**

**Abstract**
Finding solutions: what is complexity, problem solving cycle.

Implementing solutions: project management, critical path method, quality control feedback loop.

Controlling solutions: Vensim software, feedback cycles, control parameters, instabilities, chaos, oscillations and cycles, supply and demand, production functions, investment and consumption

**Objective**
A successful participant of the course is able to:

- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics
Physiological, physical, and cognitive factors in sensation, perception, and action

The lecture slides are provided as handouts — including notes and literature sources — to registered students only. All material is to be found in the course calendar.

**376-1177-00L Human Factors I**

**W 3 credits 2V**

M. Menozzi Jäckli, R. Huang, M. Siegrist

**Objective**

The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications.

**Abstract**

Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people's health, well-being, and satisfaction as well as the overall system performance.

**Content**

- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

**Literature**

- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIOS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

**376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions**

**W 3 credits 2V**

R. Riener, O. Lambercy

**Objective**

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

**Abstract**

Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

**Content**

Introduction, problem definition, overview
- Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
- Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
- Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
- Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
- Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces


Selected Journal Articles and Web Links:


VideoTact, ForeThought Development, LLC. http://my.execcpc.com/?dwysocki/videotac.html

Prerequisites / notice
Target Group: Students of higher semesters and PhD students of
- D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

401-0647-00L Introduction to Mathematical Optimization W 5 credits 2V+1U D. Adjaishvili
Abstract Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.
Objective The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.
Content Topics covered in this course include:
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.

Literature Information about relevant literature will be given in the lecture.

Prerequisites / notice
This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

151-0544-00L Metal Additive Manufacturing - Mechanical Integrity W 4 credits 3G E. Hosseini
and Numerical Analysis
Abstract An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.
Objective The main objectives of this lecture are:
- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using different commercial analysis tools (COMSOL, ANSYS, ABAQUS) for simulation of the MAM process.
Content

- Introduction to MAM (concept, application examples, pros & cons),
- Powder-bed and powder-blown metal additive manufacturing,
- Thermo-fluid analysis of additive manufacturing,
- Continuum-based thermal modeling and experimental validation techniques,
- Residual stress and distortion simulation and verification methods,
- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),
- Mechanical property prediction for MAM,
- Microstructure and mechanical response of MAM material (steels, Ti6Al4V, Inconel, Al alloys),
- Design for additive manufacturing
- Artificial intelligence for AM

Exercise sessions use COMSOL, ANSYS, BAQUS packages for analysis of MAM process. Detailed video instructions will be provided to enable students to set up their own simulations. COMSOL, ANSYS and BAQUS agreed to support the course by providing licenses for the course attendees and therefore the students can install the packages on their own systems.

Lecture notes
Handouts of the presented slides.

Literature
No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).

Prerequisites / notice
A basic knowledge of mechanical analysis, metallurgy, thermodynamics is recommended.

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Robotics, Systems and Control
The courses listed in this category “Core Courses” are recommended. Alternative courses can be chosen in agreement with the tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCSE)</td>
<td>W</td>
<td>4 credits</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
</tr>
</tbody>
</table>

Abstract
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

Objective
With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

Content
1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)
2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)
3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models
4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

Lecture notes
https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/ Class notes, handouts

Literature
- An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann
- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann
- Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press
- Lecture notes

Prerequisites / notice
Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.

The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

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</tr>
</thead>
<tbody>
<tr>
<td>151-0325-00L</td>
<td>Planning and Decision Making for Autonomous Robots</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>E. Frazzoli</td>
</tr>
</tbody>
</table>

Abstract
Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and learning aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

Objective
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

Content

Lecture notes
Course notes and other education material will be provided for free in an electronic form.

Literature
There is no required textbook, but an excellent reference is Steve LaValle's book on “Planning Algorithms.”

Prerequisites / notice
Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with basic programming (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Domain D - Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed
151-0371-00L  Advanced Model Predictive Control  W  4 credits  2V+1U  M. Zeilinger, A. Carron, L. Hewing, J. Köhler
Abstract  Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.
Objective  Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.
Content  Topics include - Review of Bayesian statistics, stochastic systems and Stochastic Optimal Control - Nominal MPC for uncertain systems (nominal robustness) - Robust MPC - Stochastic MPC - Set-membership Identification and robust data-driven MPC - Bayesian regression and stochastic data-driven MPC - MPC as safety filter for reinforcement learning
Lecture notes  Lecture notes will be provided.
Prerequisites / notice  Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control) strongly recommended. Background in linear algebra and stochastic systems recommended.

151-0532-00L  Nonlinear Dynamics and Chaos I  W  4 credits  2V+2U  G. Haller
Abstract  Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
Objective  This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.
Content  (1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance
Lecture notes  The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.
Prerequisites / notice  - Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

151-0563-01L  Dynamic Programming and Optimal Control  W  4 credits  2V+1U  R. D’Andrea
Objective  Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.
Literature  Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

151-0567-00L  Engine Systems  W  4 credits  3G  C. Onder
Abstract  Introduction to current and future engine systems and their control systems
Objective  Introduction to methods of control and optimization of dynamic systems. Application to real engines. Understand the structure and behavior of drive train systems and their quantitative descriptions.
Content  Physical description and mathematical models of components and subsystems (mixture formation, load control, supercharging, emissions, drive train components, etc.). Case studies of model-based optimal design and control of engine systems with the goal of minimizing fuel consumption and emissions.
Lecture notes  Introduction to Modeling and Control of Internal Combustion Engine Systems
Prerequisites / notice  Combined homework and testbench exercise (air-to-fuel-ratio control or idle-speed control) in groups

151-0569-00L  Vehicle Propulsion Systems  W  4 credits  3G  C. Onder, P. Elbert
Abstract  Introduction to current and future propulsion systems and the electronic control of their longitudinal behavior
Objective  Introduction to methods of system optimization and controller design for vehicles. Understanding the structure and working principles of conventional and new propulsion systems. Quantitative descriptions of propulsion systems
Content  Understanding of physical phenomena and mathematical models of components and subsystems (manual, automatic and continuously variable transmissions, energy storage systems, electric drive trains, batteries, hybrid systems, fuel cells, road/wheel interaction, automatic braking systems, etc.). Presentation of mathematical methods, CAE tools and case studies for the model-based design and control of propulsion systems with the goal of minimizing fuel consumption and emissions.
Lecture notes  Vehicle Propulsion Systems -- Introduction to Modeling and Optimization
ISBN: 978-3-642-35912-5
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronics, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.

Lectures of Prof. Dr. Ch. Onder and Dr. Ph. Elbert are also possible to be held in German.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Group</th>
<th>Instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0573-00L</td>
<td>System Modeling</td>
<td>4</td>
<td>2V+1U</td>
<td>L. Guzzella</td>
</tr>
<tr>
<td>151-0593-00L</td>
<td>Embedded Control Systems</td>
<td>4</td>
<td>6G</td>
<td>J. S. Freudenberg, M. Schmid Daners</td>
</tr>
<tr>
<td>151-0601-00L</td>
<td>Theory of Robotics and Mechatronics</td>
<td>4</td>
<td>3G</td>
<td>P. Korba, S. Stoeter</td>
</tr>
<tr>
<td>151-0604-00L</td>
<td>Microrobotics</td>
<td>4</td>
<td>3G</td>
<td>B. Nelson, N. Shamsudhin</td>
</tr>
</tbody>
</table>

**System Modeling**

**Objective**
Learn how to mathematically describe a physical system or a process in the form of a model usable for analysis and control purposes.

**Content**
This class introduces generic system-modeling approaches for control-oriented models based on first principles and experimental data. The class will span numerous examples related to mechatronics, thermodynamic, chemistry, fluid dynamic, energy, and process engineering systems. Model scaling, linearization, order reduction, and balancing. Parameter estimation with least-squares methods. Various case studies: loud-speaker, turbines, water-propelled rocket, geostationary satellites, etc. The exercises address practical examples.

**Taught competencies**

**Domain A - Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Domain C - Social Competencies**
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Domain D - Personal Competencies**
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection

**Literature**
A list of references is included in the handouts.

**Prerequisites / notice**
Prerequisite courses are Control Systems I and Informatics I.

**Course notes**
This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch)

After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

**Embedded Control Systems**

**Abstract**
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

**Objective**
Familiarize students with main architectural principles and concepts of embedded control systems.

**Content**
An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

**Lecture notes**
Lecture notes, lab instructions, supplemental material

**Prerequisites / notice**
Prerequisite courses are Control Systems I and Informatics I.

**Course notes**
This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch)

After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

**Theory of Robotics and Mechatronics**

**Abstract**
This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Objective**
Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Content**
An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

**Lecture notes**
available.

**Microrobotics**

**Abstract**
Microrobotics is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

**Objective**
The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on practical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biomedical microrobots

The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

The lecture will be taught in English.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecture Notes</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0632-00L</td>
<td>Vision Algorithms for Mobile Robotics (University of Zurich)</td>
<td>6</td>
<td>6 credits</td>
<td>W</td>
</tr>
</tbody>
</table>

**Abstract**

For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry (the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers).

**Objective**

Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry and Simultaneous Localization And Mapping (SLAM) (the algorithms behind Hololens, Facebook-Oculus Quest, and the NASA Mars rovers).

**Content**

Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab. By the end of the course, you will integrate all these building blocks into a working visual odometry algorithm.

**Lecture notes**

Lecture slides will be made available on the course official website: [http://rpg.ifi.uzh.ch/teaching.html](http://rpg.ifi.uzh.ch/teaching.html)

**Literature**


**Prerequisites / notice**

Fundamentals of algebra, geometry, matrix calculus, and Matlab programming.

**151-0565-00L**

**Skills for Creativity and Innovation**

4 credits

| W | 4 credits | 3G | I. Goller, C. Kobe |

**Abstract**

This lecture aims to enhance the knowledge and competency of students regarding their innovation capability. An overview on prerequisites and different skills for creativity and innovation in individual & team settings is given. The focus of this lecture is clearly on building competencies - not just acquiring knowledge.

- Basic knowledge about creativity and skills
- Knowledge about individual prerequisites for creativity
- Development of individual skills for creativity
- Knowledge about teams
- Development of team-oriented skills for creativity
- Knowledge and know-how about transfer to idea generation teams

**Content**

Basic knowledge about creativity and skills:
- Introduction into creativity & innovation: definitions and models

Knowledge about individual prerequisites for creativity:
- Personality, motivation, intelligence
- Development of individual skills for creativity:
  - Focus on creativity as problem analysis & solving
  - Individual skills in theoretical models
  - Individual competencies: exercises and reflection

Knowledge about teams:
- Definitions and models
- Roles in innovation processes
- Development of team-oriented skills for creativity:
  - Idea generation and development in teams
  - Cooperation & communication in innovation teams
- Knowledge and know-how about transfer to idea generation teams:
  - Self-reflection & development planning
  - Methods of knowledge transfer

**Lecture notes**

Slides, script and other documents will be distributed via moodle.ethz.ch (access only for students registered to this course)

**Literature**


As well as material handed out in the lecture.
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems and devices. Topics are changing every year.

- Further training with specialized lectures and large participation from the industry.

Language: Help for English speaking students on request.

### 151-0851-00L: Robot Dynamics

**Abstract**
We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

**Objective**
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

**Content**
The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

**Prerequisites / notice**
- Students must have participated and passed the courses Manufacturing, Production Machines I and Forming Technology III - Forming Processes.

### 151-0905-00L: Medical Technology Innovation - From Concept to Clinics

**Abstract**
Project-oriented learning on how to develop technological solutions to address unmet clinical needs.

**Objective**
After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

**Literature**
The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

**Prerequisites / notice**
- Further training with specialized lectures and large participation from the industry.

### 151-0917-00L: Mass Transfer

**Abstract**
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

**Objective**
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

**Content**
Fick’s laws; application and significance of mass transfer; comparison of Fick’s laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

**Literature**

**Prerequisites / notice**
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

### 151-1116-00L: Introduction to Aircraft and Car Aerodynamics

**Abstract**
Aircraft aerodynamics: Atmosphere; aerodynamic forces (lift, drag); thrust.

An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics.

To understand the basic relations of the origin of aerodynamic forces (i.e., lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components.

Illustration of the intrinsic problems and results using examples.

Using experimental and theoretical methods to illustrate possibilities and limits.


Aircraft aerodynamics: Atmosphere, aerodynamic forces (ascending force: profile, wings. Resistance, residual resistance, induced resistance); thrust (overview of the propulsion system, aerodynamics of the propellers), introduction to static longitudinal stability.

Preparation materials & slides are provided prior to each class.

Embedded System Design: Prior to class preparation materials & slides are provided.

Objective

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.

Understanding specific requirements and problems arising in embedded system applications.

Using the formal models and methods in embedded system design in practical applications using the programming language C, the operating system FreeRTOS, a commercial embedded system platform, and the associated design environment.

The focus of this lecture is on the design of embedded systems using formal models and methods as well as computer-based synthesis methods. Besides, the lecture is complemented by laboratory sessions where students learn to program in C, to base their design on the embedded operating system FreeRTOS, to use a commercial embedded system platform including sensors, and to edit/debug via an integrated development environment.

Specifically the following topics will be covered in the course: Embedded system architectures and components, hardware-software interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.

More information is available at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Prerequisites / notice

Prerequisites: Basic knowledge in computer architectures and programming.

Abstract

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.

The following information will be available: Lecture material, publications, exercise sheets and laboratory documentation at https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html.

Literature


Prerequisites / notice

Prerequisites: Basic knowledge in computer architectures and programming.
Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

4 credits

1S

Current topics in Systems and Control presented mostly by external speakers from academia and industry

F. Dörfler
D. Bortis

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on

This course provides the basics of relational databases from the perspective of the user.

see above

Analytical Competencies

, E. Konukoglu, F. Yu

Fundamentals of Electric Machines

Course material Script, computer demonstrations, exercises and problem solutions

Lecture notes and associated exercises including correct answers

L. Van Gool

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

2V+1U

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes
Lecture notes and associated exercises including correct answers

System Identification

Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

4 credits

2V+1U

R. Smith

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.


Additional papers will be available via the course Moodle.

Control systems (227-0216-00L) or equivalent.

Seminar in Systems and Control

Current topics in Systems and Control presented mostly by external speakers from academia and industry

see above

Information Systems for Engineers

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

4 credits

2V+1U

G. Fourny

Domain A - Subject-specific Competencies

Concepts and Theories

Assessed

Domain B - Method-specific Competencies

Analytical Competencies

Assessed

Domain D - Personal Competencies

Critical Thinking

Not assessed

Integrity and Work Ethics

Not assessed

227-0447-00L Image Analysis and Computer Vision

W 6 credits 3V+1U

L. Van Gool, E. Konukoglu, F. Yu

Abstract


Objective

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux.

The course language is English.

227-0517-10L Fundamentals of Electric Machines

W 6 credits 4G

D. Bortis

Abstract

This course introduces to different electric machine concepts and provides a deeper understanding of their detailed operating principles. Different aspects arising in the design of electric machines, like dimensioning of magnetic and electric circuits as well as consideration of mechanical and thermal constraints, are investigated. The exercises are used to consolidate the concepts discussed.

Objective

The objective of this course is to convey knowledge on the operating principles of different types of electric machines. Further objectives are to evaluate machine types for given specifications and to acquire the ability to perform a rough design of an electrical machine while considering the versatile aspects with respect to magnetic, electrical, mechanical and thermal limitations. Exercises are used to consolidate the presented theoretical concepts.

Content

- Fundamentals in magnetic circuits and electromechanical energy conversion.
- Force and torque calculation.
- Operating principles, magnetic and electric modelling and design of different electric machine concepts: DC machine, AC machines (permanent magnet synchronous machine, reluctance machine and induction machine).
- Complex space vector notation, rotating coordinate system (dq-transformation).
- Loss components in electric machines, scaling laws of electromechanical actuators.
- Mechanical and thermal modelling.

Lecture notes
Lecture notes and associated exercises including correct answers

227-0689-00L System Identification

W 4 credits 2V+1U

R. Smith

Abstract

Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.

Objective

To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.

Content

Introduction to modeling: Black-box and grey-box models; Parametric and non-parametric models; ARX, ARMAX (etc.) models.

Predictive, open-loop, black-box identification methods. Time and frequency domain methods. Subspace identification methods.

Optimal experimental design, Cramer-Rao bounds, input signal design.

Parametric identification methods. On-line and batch approaches.

Closed-loop identification strategies. Trade-off between controller performance and information available for identification.


Additional papers will be available via the course Moodle.

Control systems (227-0216-00L) or equivalent.

227-0920-00L Seminar in Systems and Control

Z 0 credits 1S

F. Dörfler, R. D'Andrea, E. Frazzoli, M. H. Khammash, J. Lygeros, R. Smith

Abstract

Current topics in Systems and Control presented mostly by external speakers from academia and industry

Objective

see above

252-0834-00L Information Systems for Engineers

W 4 credits 2V+1U

G. Fourny

Abstract

This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).
Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Map cube queries to SQL.
14. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice

For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logics
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Human Computer Interaction

252-3110-00L

Number of participants limited to 150.

Abstract

The course provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design. Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can inform the design of new interfaces, systems and technologies.

Objective

The goal of the course is that students should understand the principles of user-centred design and be able to apply these in practice. As well as understand the basic notions of Computational Design in a HCI context.

Content

The course will introduce students to various methods of analysing the user experience, showing how these can be used at different stages of system development from requirements analysis through to usability testing. Students will get experience of designing and carrying out user studies as well as analysing results. The course will also cover the basic principles of interaction design. Practical exercises related to touch and gesture-based interaction will be used to reinforce the concepts introduced in the lecture. To get students to further think beyond traditional system design, we will discuss issues related to ambient information and awareness.

The course website can be found here:
https://teaching.siplab.org/human_computer_interaction/2021/

Probabilistic Artificial Intelligence

263-5210-00L

This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.
Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
Solid basic knowledge in statistics, algorithms and programming.
The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Computer Vision

Abstract
The goal of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective
The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content
Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice
It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Abstract
Rehabilitation Engng is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective
Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Content
Introduction, problem definition, overview
Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces
Literature

Introductory Books:

Selected Journal Articles and Web Links:

Prerequisites / notice

Target Group:
- Students of higher semesters and PhD students of D-MAVT, D-ITET, D-INFK, D-HEST
- Biomedical Engineering, Robotics, Systems and Control
- Medical Faculty, University of Zurich
- Students of other departments, faculties, courses are also welcome

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

Abstract

Physical Human Robot Interaction (pHRI) ■ W 4 credits 2V+2U O. Lambercy

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) compare and select mechatronic components that optimally fulfill the defined design requirements;
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.
This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for human systems such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

Lecture notes
Will be distributed on Moodle before the lectures.

Literature

Prerequisites / notice
The registration is limited to 26 students.
There are 4 credit points for this lecture.
The lecture will be held in English.
The students are expected to have basic control knowledge from previous classes.
http://www.relab.ethz.ch/education/courses/phri.html

Micro & Nanosystems
The courses listed in this category "Core Courses" are recommended. Alternative courses can be chosen in agreement with the tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCE) I</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
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</tbody>
</table>

Abstract
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

Objective
With manufacturing processes reaching its limits in terms of transistor density on today's computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the "think parallel" mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.
This class introduces theoretical and practical aspects related to the modeling and simulation of multiphysics systems. Students will learn fundamentals of the emerging field of microrobotics. This includes a focus on intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as unexperienced users will soon find themselves in front of frustrating error messages or incomprehensible results.

Examples will mainly come from the fields of mechanics (continuum mechanics), electromagnetism (Maxwell equations), heat transport (Fourier equation) and combinations of these domains.

Lecture notes: Comsol Multiphyics will be utilized to apply the concepts learned during the lectures to solve exercises.

Prerequisites / notice: Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.

Content: This course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

Lecture notes: The lecture will be taught in English.

Prerequisites / notice: Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.

Content: Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.

Lecture notes: The lecture will be taught in English.

Prerequisites / notice: Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.
The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

Self-assembly and directed assembly of 2D and 3D structures.


Prerequisites / notice

Lectures and Mini-Review presentations: Thursday 10-13

Homework: Mini-Review (compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illustrates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be immediately reported and as a written paper.

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151-0620-00L Embedded MEMs Lab W 5 credits 3P C. Hierold, S. Blunier, M. Haluska

Abstract
Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report. Limited access

Objective
Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

Content
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

Lecture notes
A document containing theory, background and practical course content is distributed at the introductory lecture day of the course.

Literature
The document provides sufficient information for the participants to successfully participate in the course.

Prerequisites / notice
Participating students are required to attend all scheduled lectures and meetings of the course.

Participating students are required to provide proof that they have personal accident insurance prior to the start of the laboratory portion of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"
Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Profs Daraio, Dual, Hierold, Koumoutsakos, Nelson, Norris, Poulikakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.
Priority 4: all other students (PhD, bachelor, master) with a background in silicon or microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade and by (in following order) priority group.

The course is offered in autumn and spring semester.

151-0621-00L Microsystems I: Process Technology and Integration W 6 credits 3V+3U M. Haluska, C. Hierold

Abstract
Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

Objective
Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystems devices by the combination of unit process steps (= process flow).

Content
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.
- Application of selected technologies will be demonstrated on case studies.

Lecture notes
Handouts (available online)
### Literature
- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O. Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

### Prerequisites / notice
Prerequisites: Physics I and II

### 151-0642-00L Seminar on Micro and Nanosystems

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<th>C. Hierold</th>
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</table>

**Abstract**
Scientific presentations from the field of Micro- and Nanosystems

**Objective**
In particular, the seminar addresses students, who are interested in scientific work in the field of Micro- and Nanosystem technologies, or who have started already with it. Respectively, current examples in the research will be discussed.

**Content**
Current themes in the field of Micro- and Nanosystem technologies using the examples of intern and extern research groups, as well as ongoing themes of study-, diplom- and doctoral thesis will be introduced and discussed. The scope of the seminar is broadened by occasional guest speakers.

### 151-0911-00L Introduction to Plasmonics

<table>
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<tr>
<th>W</th>
<th>4 credits</th>
<th>2V+1U</th>
<th>D. J. Norris</th>
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**Abstract**
This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.

**Objective**
Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

**Content**

- Fundamentals of Plasmonics
  - Basic electromagnetic theory
  - Optical properties of metals
  - Surface plasmon polaritons on surfaces
  - Surface plasmon polariton propagation
  - Localized surface plasmons

- Applications of Plasmonics
  - Waveguides
  - Extraordinary optical transmission
  - Enhanced spectroscopy
  - Sensing
  - Metamaterials

**Lecture notes**
Class notes and handouts

**Literature**

**Prerequisites / notice**
Master of MNS, MAVT, ITET, Physics

### 151-0913-00L Introduction to Photonics

<table>
<thead>
<tr>
<th>W</th>
<th>4 credits</th>
<th>2V+2U</th>
<th>R. Quidant, J. Ortega Arroyo</th>
</tr>
</thead>
</table>

**Abstract**
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

**Objective**
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
Content

I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel equations
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

VI- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

VII- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Plasmonic trapping
6) Applications of optical tweezers

Abstract
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Objective
This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.

Content
Fick’s laws; application and significance of mass transfer; comparison of Fick’s laws with Newton’s and Fourier’s laws; derivation of Fick’s 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.

Literature

Prerequisites / notice
Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

151-0931-00L Seminar on Particle Technology Z 0 credits 3S S. E. Pratsinis, S. E. Pratsinis

Abstract
The goal of the lecture is to convey a basic knowledge in the area of PV materials as well as their construction and production processes and to empower the students to apply the knowledge gained to address current problems in research and practice.

Objective
Students attend and give research presentations for the research they plan to do and at the end of the semester they defend their results and answer questions from research scientists. Familiarize the students with the latest in this field.

151-0931-00L Information Systems for Engineers W 4 credits 2V+1U G. Fourny

Abstract
The goal of the lecture is to convey a basic knowledge in the area of PV materials as well as their construction and production processes and to empower the students to apply the knowledge gained to address current problems in research and practice.

Objective
Students attend and give research presentations for the research they plan to do and at the end of the semester they defend their results and answer questions from research scientists. Familiarize the students with the latest in this field.
Abstract
This course provides the basics of relational databases from the perspective of the user. We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective
This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality.
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content
Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

Literature
- Lecture material (slides).
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (It is not required to buy the book, as the library has it)

Prerequisites / notice
For non-CS/DS students only, BSc and MSc Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Bioengineering
The courses listed in this category “Core Courses” are recommended. Alternative courses can be chosen in agreement with the tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCSE) I</td>
<td>W</td>
<td>4 credits</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
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</tbody>
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Abstract
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.
With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)
2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)
3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models
4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders. Solving partial differential equations (PDEs) using grid-based and particle methods

Lecture notes https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/
Class notes, handouts

Prerequisites / notice Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

**151-0317-00L Visualization, Simulation and Interaction - Virtual Reality II**

**Abstract**
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

**Objective**
Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data, the interaction of the human user with the digital environment, or the use of augmented reality systems. The goal of the lecture is to provide a deeper knowledge of today’s VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

**Content**
Introduction into Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of simulation; compression procedures of image-, audio-, and video signals; new materials for force feedback devices; introduction into data security; cryptography; definition of free-form surfaces; digital factory; new research fields of virtual reality

**Lecture notes**
The handout is available in German and English.

**Prerequisites / notice**
"Visualization, Simulation and Interaction - Virtual Reality I" is recommended, but not mandatory.

**Didactical concept:**
The course consists of lectures and exercises.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Media and Digital Technologies</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
</tr>
</tbody>
</table>

**151-8101-00L International Engineering: from Hubris to Hope**

**Abstract**
Since Europe surrendered their colonial assets, engineers from rich countries have returned to the African continent to address the real and perceived ills that they felt technology could solve. And yet, 70 years on, the promise of technology has largely failed to deliver widespread, substantive improvements in the quality of life. Why?

**Objective**
This course is meant for engineers who are interested in pursuing an ethical and relevant career internationally, and who are willing to examine the complex role that well-meaning foreigners have played and continue to play in the disappointing health outcomes that characterize much of the African continent.

After completing the course, participants will be able to
- critique the jargon and terms used by the international community, i.e. “development”, “aid”, “cooperation”, “assistance” “third world” “developing” “global south” “low and middle-income” and justify their own chosen terminology
- recognize the role of racism and white-supremacy in the development of the Aid industry
- understand the political, financial, and cultural reasons why technology and infrastructure have historically failed
- Debate the merits of international engineering in popular culture and media
- Propose improved SDG indicators that address current shortcomings
- Compare the engineering curricula of different countries to identify relative strengths and shortcomings
- Explain the inherent biases of academic publishing and its impact on engineering failure
- Analyse linkages between the rise of philanthropy and strategic priority areas
- Recommend equitable, just funding models to achieve more sustainable outcomes
- Formulate a vision for the international engineer of the future
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Language</th>
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<tbody>
<tr>
<td>151-0917-00L</td>
<td>Mass Transfer</td>
<td>W</td>
<td>4</td>
<td></td>
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<tr>
<td></td>
<td>Introduction to Biomedical Engineering</td>
<td>3G</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomedical Imaging</td>
<td>W</td>
<td>6</td>
<td>S. Kozerke, K. P. Prüssmann</td>
</tr>
<tr>
<td></td>
<td>Biomedical Engineering</td>
<td>W</td>
<td>4</td>
<td>J. Vörös, S. J. Ferguson, S. Kozerke, M. P. Wolf, M. Zenobi-Wong</td>
</tr>
<tr>
<td></td>
<td>Bioelectronics and Biosensors</td>
<td>W</td>
<td>6</td>
<td>J. Vörös, M. F. Yanik</td>
</tr>
</tbody>
</table>

**Objective**

- Learn about the remaining challenges in this field
- Be able to solve typical problems in biosensing and bioelectronics
- Learn the basic concepts in biosensing and bioelectronics

**Abstract**

This course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

**Content**

- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Literature**

- Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011
- Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

**Prerequisites / notice**

Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.

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**Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques**

- Role of international engineering during colonialism
- Transition of international engineering following colonialism
- White saviourism and racism in international engineering
- International engineering in popular culture
- The missing role of Engineering Education
- Biases academic publishing
- The emerging role in Global Philanthropy
- The paradox of International funding

**Literature**

Content

L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical bioensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics. In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

227-0447-00L Image Analysis and Computer Vision W 6 credits

Abstract

Objective
Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content
This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes
Course material Script, computer demonstrations, exercises and problem solutions

Prerequisites / notice
Prerequisites:
Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

227-0939-00L Cell Biophysics W 6 credits

Abstract
Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.
Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life’s mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content

- Basics of theory of probability
- Boltzmann’s law
- Entropy maximization and Gibbs free energy minimization
- Ligand-receptor: two-state systems and the MWC model
- Random walks, diffusion, crowding
- Electrostatics for salty solutions
- Elasticity: fibers and membranes
- Molecular motors
- Action potential: Hodgkin-Huxley model
- Photosynthesis and vision
- Gene regulation
- Development: Turing patterns
- Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o’clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Prerequisites / notice

Participants need a good command of
- differentiation and integration of a function with one or more variables (basics of Analysis),
- Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

Literature


Domain A - Subject-specific Competencies

Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Domain C - Social Competencies

Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Domain D - Personal Competencies

Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

227-0945-00L Cell and Molecular Biology for Engineers I

This course is part I of a two-semester course.

W 3 credits 2G C. Frei

Abstract

The course gives an introduction into cellular and molecular biology, specifically for students with a background in engineering. The focus will be on the basic organization of eukaryotic cells, molecular mechanisms and cellular functions. Textbook knowledge will be combined with results from recent research and technological innovations in biology.

Objective

After completing this course, engineering students will be able to apply their previous training in the quantitative and physical sciences to modern biology. Students will also learn the principles how biological models are established, and how these models can be tested.

Content

Lectures will include the following topics (part I and II): DNA, chromosomes, genome engineering, RNA, proteins, genetics, synthetic biology, gene expression, membrane structure and function, vesicular traffic, cellular communication, energy conversion, cytoskeleton, cell cycle, cellular growth, apoptosis, autophagy, cancer and stem cells.

In addition, 4 journal clubs will be held, where recent publications will be discussed (2 journal clubs in part I and 2 journal clubs in part II). For each journal club, students (alone or in groups of up to three students) have to write a summary and discussion of the publication. These written documents will be graded and count as 40% for the final grade.

Lecture notes

Scripts of all lectures will be available.

Literature

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale will be indicated during the lecture.

Handouts and relevant literature will be provided.

The course also covers support for data cubes (analytics).

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it.

The course provides the basics of relational databases from the perspective of the user.

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Objective

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.

2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).

3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.

4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality

5. Explain what bad design is and why it matters.

6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".

7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.

8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.

9. Explain what data independence is all about and didn't age a bit since the 1970s.

10. Explain, in the big picture, how a relational database is physically implemented.

11. Know and deal with the natural syntax for relational data, CSV.

12. Explain the data cube model including slicing and dicing.

13. Store data cubes in a relational database.

14. Map cube queries to SQL.

15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook

Literature

- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites

For non-CS/DS students only, BSc and MSc

- Elementary knowledge of set theory and logics
- Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

376-0121-00L Multiscale Bone Biomechanics W 6 credits 4S R. Müller, X.-H. Qin

Number of participants limited to 30

Abstract

Imaging and computing methods are key to advances and innovation in medicine. This course introduces established fundamentals as well as modern techniques and methods of imaging and computing in medicine.

1. Understanding and practical implementation of biosignal processes methods for imaging
2. Understanding of imaging techniques including radiation imaging, radiographic imaging systems, computed tomography imaging, diagnostic ultrasound imaging, and magnetic resonance imaging
3. Knowledge of computing, programming, modelling and simulation fundamentals
4. Computational and systems thinking as well as scripting and programming skills
5. Understanding and practical implementation of emerging computational methods and their application in medicine including artificial intelligence, deep learning, big data, and complexity
6. Understanding of the emerging concept of personalised and in silico medicine
7. Encouragement of critical thinking and creating an environment for independent and self-directed studying
Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance. The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Lectures will be given in English.

- Human Factors I: W 3 credits 2V
- Human Factors II: Rehabilitation of Sensory and Vegetative Functions: W 3 credits 2V

Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Rehabilitation Engineering is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

- Brain-Computer Interfaces
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain stimulation and recording
- Rehabilitative use of kinesthetic and tactile function
- Rehabilitation and use of kinesthetic and tactile function
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
- Rehabilitation of vestibular function
- Rehabilitation of auditory function
- Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter

This lecture is independent from Rehabilitation Engineering I. Thus, both lectures can be visited in arbitrary order.

376-1177-00L Human Factors I

Abstract

- Strategies of human-system-interaction, individual needs, physical & mental abilities, and system properties are key factors affecting the quality and performance in interaction processes. In the lecture, factors are investigated by basic scientific approaches. Discussed topics are important for optimizing people’s health, well-being, and satisfaction as well as the overall system performance.

Objective

- The goal of the lecture is to empower students in better understanding the applied theories, principles, and methods in various applications. Students are expected to learn about how to enable an efficient and qualitatively high standing interaction between human and the environment, considering costs, benefits, health, and safety as well. Thus, an ergonomic design and evaluation process of products, tasks, and environments may be promoted in different disciplines. The goal is achieved in addressing a broad variety of topics and embedding the discussion in macroscopic factors such as the behavior of consumers and objectives of economy.

Content

- Physiological, physical, and cognitive factors in sensation, perception, and action
- Body spaces and functional anthropometry, Digital Human Models
- Experimental techniques in assessing human performance, well-being, and comfort
- Usability engineering in system designs, product development, and innovation
- Human information processing and biological cybernetics
- Interaction among consumers, environments, behavior, and tasks

Literature

- Gavriel Salvendy, Handbook of Human Factors and Ergonomics, 4th edition (2012), is available on NEBIS as electronic version and for free to ETH students
- Further textbooks are introduced in the lecture
- Brouchures, checklists, key articles etc. are uploaded in ILIAS

376-1219-00L Rehabilitation Engineering II: Rehabilitation of Sensory and Vegetative Functions

Abstract

- Rehabilitation Engineering is the application of science and technology to ameliorate the handicaps of individuals with disabilities to reintegrate them into society. The goal is to present classical and new rehabilitation engineering principles applied to compensate or enhance motor, sensory, and cognitive deficits. Focus is on the restoration and treatment of the human sensory and vegetative system.

Objective

- Provide knowledge on the anatomy and physiology of the human sensory system, related dysfunctions and pathologies, and how rehabilitation engineering can provide sensory restoration and substitution.

Content

- Introduction, problem definition, overview
- Rehabilitation of visual function
- Anatomy and physiology of the visual sense
- Technical aids (glasses, sensor substitution)
- Retina and cortex implants
- Rehabilitation of hearing function
- Anatomy and physiology of the auditory sense
- Hearing aids
- Cochlea Implants
- Rehabilitation and use of kinesthetic and tactile function
- Anatomy and physiology of the kinesthetic and tactile sense
- Tactile/haptic displays for motion therapy (incl. electrical stimulation)
- Role of displays in motor learning
- Rehabilitation of vestibular function
- Anatomy and physiology of the vestibular sense
- Rehabilitation strategies and devices (e.g. BrainPort)
- Rehabilitation of vegetative Functions
- Cardiac Pacemaker
- Phrenic stimulation, artificial breathing aids
- Bladder stimulation, artificial sphincter
- Brain stimulation and recording
- Deep brain stimulation for patients with Parkinson, epilepsy, depression
- Brain-Computer Interfaces

The course is structured as a seminar in three parts of 45 minutes with video lectures and a flipped classroom setup: in the first part (TORQUEs: Tiny, Open-with-Restrictions courses focused on QUality and Effectiveness), students study the basic concepts in short, interactive video lectures on the online learning platform Moodle. Students are able to post questions at the end of each video lecture or the Moodle forum that will be addressed in the second part of the lectures using a flipped classroom concept. For the flipped classroom, the lecturers may prepare additional teaching material to answer the posted questions (Q&A). Following the Q&A, the students will form small groups to acquire additional knowledge using online, python-based activities via JupyterHub or additionally distributed material and discuss their findings in teams. Learning outcomes will be reinforced with weekly Moodle assignments, to be completed during the flipped classroom portion.

Lectures will be given in English.

M. Menozzi Jäckli

M. Siegrist
Literature

Introductory Books:


Selected Journal Articles and Web Links:

- VideoTact, ForeThought Development, LLC. http://my.execpc.com/?dwysocki/videotac.html

376-1504-00L Physical Human Robot Interaction (pHRI)  W 4 credits 2V+2U O. Lambercy

Abstract

This course focuses on the emerging, interdisciplinary field of physical human-robot interaction, bringing together themes from robotics, real-time control, human factors, haptics, virtual environments, interaction design and other fields to enable the development of human-oriented robotic systems.

Objective

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and de- sign safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1) identify critical human factors in physical human-robot interaction and use these to derive design requirements;
2) compare and select mechatronic components that optimally fulfill the defined design requirements;
3) derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4) design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5) characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6) investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

4. Introduction to different material classes in use for medical applications.

Lecture notes
Will be distributed on Moodle before the lectures.

Literature

Prerequisites / notice
The registration is limited to 26 students. There are 4 credit points for this lecture. The lecture will be held in English. The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html

376-1550-00L Clinical and Movement Biomechanics W 4 credits 3G N. Singh, R. List, P. Schütz

Number of participants limited to 50.

Abstract
Measurement and modeling of the human movement during daily activities and in a clinical environment.

Objective
The students are able to analyse the human movement from a technical point of view, to process the data and perform modeling with a focus towards clinical application.

Content
This course includes study design, measurement techniques, clinical testing, accessing movement data and analysis as well as modeling with regards to human movement.

376-1714-00L Biocompatible Materials W 4 credits 3V K. Maniura, M. Rottmar, M. Zenobi-Wong

Abstract
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.
Trauma Biomechanics

Lecture notes
Handouts are deposited online (moodle).

Literature:

(available online via ETH library)

Handouts and references therein.

402-0341-00L Medical Physics I W 6 credits 2V+1U P. Manser

Abstract
Introduction to the foundations of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

Objective
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefit of patients and the society. The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the exercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

Lecture notes
A script will be provided.

Prerequisites / notice
For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

551-0319-00L Cellular Biochemistry (Part I) W 3 credits 2V U. Kutay, G. Neurohr, M. Peter, K. Weis, I. Zemp

Abstract
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

Objective
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry. The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

Content
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes. Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

Lecture notes
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biolog.ethz.ch)

Literature
Recommended supplementary literature (review articles and selected primary literature) will be provided during the course.
Prerequisites / notice
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

Design, Computation, Product Development & Manufacturing

The courses listed in this category “Core Courses” are recommended. Alternative courses can be chosen in agreement with the tutor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-3209-00L</td>
<td>Engineering Design Optimization</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>K. Shea, T. Stankovic</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td>The course covers fundamentals of computational optimization methods in the context of engineering design. It develops skills to formally state and model engineering design tasks as optimization problems and select appropriate methods to solve them.</td>
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<td>The lecture and exercises teach the fundamentals of optimization methods in the context of engineering design. After taking the course students will be able to express engineering design problems as formal optimization problems. Students will also be able to select and apply a suitable optimization method given the nature of the optimization model. They will understand the links between optimization and engineering design in order to design more efficient and performance optimized technical products. The exercises are MATLAB based.</td>
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<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>1. Optimization modeling and theory</td>
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<td>2. Unconstrained optimization methods</td>
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<td>3. Constrained optimization methods - linear and non-linear</td>
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<td>4. Direct search methods</td>
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<td>5. Stochastic and evolutionary search methods</td>
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<td>6. Multi-objective optimization</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td>available on Moodle</td>
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<tr>
<th>151-3215-00L</th>
<th>Design for Additive Manufacturing ■</th>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This course is focusing on design, development and innovation with Additive Manufacturing (AM) production technologies. Part of the course is a project, where students design and produce their own functional AM part in metal, with selective laser melting (SLM). The different designs of the students will be analyzed and an the design will be optimized.</td>
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<td><strong>Objective</strong></td>
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<td>To provide a fundamental knowledge of Additive Manufacturing (AM) and generate experience and knowledge in the field of the design for AM (DiAM), product development and value creation with AM.</td>
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<td><strong>Content</strong></td>
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<td>Parallel to the lectures the students design SLM prototypes in a project. Further, the prototypes going to be manufactured and possible optimizations will be discussed in the group.</td>
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<td>The course is addressing the following topics:</td>
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<td>- AM-Processes including SLM, SLS and FDM</td>
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<td>- AM-Principles</td>
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<td>- Materialise Magics-Introduction</td>
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<td>- AM-Guidelines</td>
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<td>- Value added chain of AM</td>
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<td>- AM-Quality management</td>
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<td>- Microstructures and materials for AM</td>
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<td>- Industry cases of AM</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>Script and handouts are available in PDF-format.</td>
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<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Christoph Klahn; Mirko Meboldt: Entwicklung und Konstruktion für die Additive Fertigung - Grundlagen und Methoden für den Einsatz in industriellen Endkundenprodukten</td>
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<tr>
<td></td>
<td>Vogel Business Media, Würzburg</td>
</tr>
<tr>
<td></td>
<td>ISBN: 978-3-8343-3395-7</td>
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<tr>
<td></td>
<td>Ian Gibson; David Rosen; Brent Stucker: Additive manufacturing technologies - 3D printing, rapid prototyping, and direct digital manufacturing</td>
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<tr>
<td></td>
<td>Springer, New York</td>
</tr>
<tr>
<td></td>
<td>ISBN: 978-1-4939-2112-6</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td>Master's students</td>
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<td>Registering to the course requires fulfilling the semester performance (active participation in the semester project and oral exam). If the semester project or the oral exam is missing the course is not passed (Abbruch). Final grades are based on a mixture of design projects (60%) and oral exam (40%). The language of the projects and the presentation can be English or German, depending on the student's preference.</td>
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<tr>
<td>252-0834-00L</td>
<td>Information Systems for Engineers</td>
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<td><strong>Abstract</strong></td>
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<td>This course provides the basics of relational databases from the perspective of the user.</td>
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<td>We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).</td>
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</table>

Autumn Semester 2021
Objective
This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content

Using a relational database
===================================
1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level
===================================
6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database
===================================
12. Data cubes

Outlook
===================================
13. Outlook

Literature
- Lecture material (slides).
  (It is not required to buy the book, as the library has it)
- Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

363-1065-00L Design Thinking: Human-Centred Solutions to Real World Challenges
5 credits
5G
S. Brusoni

Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Design Thinking: Human-Centred Solutions to Real World Challenges
Does not take place this semester.

Information and application: http://sparklabs.ch/
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validated them through quick iterations of prototyping and testing using different tools and materials.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

### Multidisciplinary Courses
The students are free to choose individually from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html) and St. Gallen.

### Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-1002-00L</td>
<td>Semester Project Mechanical Engineering</td>
<td>O</td>
<td>8</td>
<td>17A</td>
<td>Professors</td>
</tr>
<tr>
<td></td>
<td>Only for Mechanical Engineering MSc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The subject of the Semester Project and the choice of the supervisor (ETH-professor) are to be approved in advance by the tutor.

Abstract
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program.

### Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1090-00L</td>
<td>Industrial Internship</td>
<td>O</td>
<td>8</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Access to the company list and request for recognition under www.mavt.ethz.ch/praxis.

No registration required via myStudies.

Abstract
The main objective of the minimum twelve-week internship is to expose Master’s students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

Objective
The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

### GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MAVT.

### Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1001-00L</td>
<td>Master’s Thesis Mechanical Engineering</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Students who fulfill the following criteria are allowed to begin with their Master's Thesis:

a. successful completion of the bachelor program;
b. fulfilling of any additional requirements necessary to gain admission to the master programme;
c. successful completion of the semester project and industrial internship;
d. achievement of 28 ECTS in the category "Core Courses".

The Master’s Thesis must be approved in advance by the tutor and is supervised by a professor of ETH Zurich.

Abstract
Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Objective
The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0173-AAL</td>
<td>Linear Algebra I and II</td>
<td>E-</td>
<td>6</td>
<td>13R</td>
<td>N. Hungerbühler</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Linear algebra is an indispensable tool of engineering mathematics. The course is an introduction to basic methods and fundamental concepts of linear algebra and its applications to engineering sciences.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Objective</td>
<td>After completion of this course, students are able to recognize linear structures and to apply adequate tools from linear algebra in order to solve corresponding problems from theory and applications. In addition, students have a basic knowledge of the software package Matlab.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Systems of linear equations, Gaussian elimination, solution space, matrices, LR decomposition, determinants, structure of linear spaces, normed vector spaces, inner products, method of least squares, QR decomposition, introduction to MATLAB, applications. Linear maps, kernel and image, coordinates and matrices, coordinate transformations, norm of a matrix, orthogonal matrices, eigenvalues and eigenvectors, algebraic and geometric multiplicity, eigenvasis, diagonalizable matrices, symmetric matrices, orthonormal basis, condition number, linear differential equations, Jordan decomposition, singular value decomposition, examples in MATLAB, applications.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>Gilbert Strang &quot;Introduction to linear algebra&quot;, Wellesley-Cambridge Press: Chapters 1-6, 7.1-7.3, 8.1, 8.2, 8.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| 406-0353-AAL | Analysis III                   | E-   | 4    | 9R    | A. Iozzi |
|            | Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit. |
| Abstract  | Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics. |
| Objective | Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations. |
| Content   | Laplace Transforms: |
|           | - Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting |
|           | - Transforms of Derivatives and Integrals, ODEs |
|           | - Unit Step Function, t-Shifting |
|           | - Short Impulses, Dirac's Delta Function, Partial Fractions |
|           | - Convolution, Integral Equations |
|           | - Differentiation and Integration of Transforms |
|           | Fourier Series, Integrals and Transforms: |
|           | - Fourier Series |
|           | - Functions of Any Period p=2L |
|           | - Even and Odd Functions, Half-Range Expansions |
|           | - Forced Oscillations |
|           | - Approximation by Trigonometric Polynomials |
|           | - Fourier Integral |
|           | - Fourier Cosine and Sine Transform |
| Partial Differential Equations: |
| - Basic Concepts |
| - Solution by separation of variables; use of Fourier series |
| - D'Alembert Solution of Wave Equation, Characteristics |
| - Heat Equation: Solution by Fourier Series |
| - Heat Equation: Solutions by Fourier Integrals and Transforms |
| - Modeling Membrane: Two Dimensional Wave Equation |
| - Laplacian in Polar Coordinates; Circular Membrane, Fourier-Bessel Series |
| - Solution of PDEs by Laplace Transform |
| For reference/complement of the Analysis I/III courses: | Christian Blatter: Ingenieur-Analyis (Download PDF) |
| Prerequisites / notice | Up-to-date information about this course can be found at: <a href="http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet">http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet</a> |</p>
<table>
<thead>
<tr>
<th>Mechanical Engineering Master - Key for Type</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Thematische Schwerpunkte:
R. Schumacher
Lecturers
Hours
Erwin Stern
M. Berkowitz Biran
Human Intelligence
1S
Cognitively Activating Instructions in MINT Subjects
- Get to know cognitively activating instructions in MINT subjects
In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-
ECTS
2V
Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and
, T. Braas,
This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of
Title
Human Learning (EW1)
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher’s work.
- To get information about recent literature on learning and instruction
Prerequisites / notice
This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Thematische Schwerpunkte: Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Foilien werden zur Verfügung gestellt.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>This course is only apt for students who intend to enrol in the programs &quot;Lehrdiplom&quot; or &quot;Didaktisches Zertifikat&quot;.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-11L</td>
<td>Gender Issues in Education and STEM</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas, C. M. Thurn</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.</td>
<td></td>
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</tr>
</tbody>
</table>
| Objective  | - To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher’s work. |
| Content    | Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them. The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar. |
| Prerequisites / notice | Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1). |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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</tr>
</tbody>
</table>
| Objective  | - Get to know cognitively activating instructions in MINT subjects
- Get information about recent literature on learning and instruction |
| Prerequisites / notice | Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht. |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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</tr>
<tr>
<td>Number of participants limited to 30.</td>
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</tr>
<tr>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning&quot;.</td>
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</tr>
</tbody>
</table>
Abstract
The focus will be on the book "Intelligenz: Grosse Unterschiede und ihre Folgen" by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.

Objective
- Understanding research methods used in the empirical human sciences
- Getting to know intelligence tests
- Understanding findings relevant for education

851-0242-08L
Research Methods in Educational Science
Number of participants limited to 30
This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW1)"

Abstract
Literature from the learning sciences is critically discussed with a focus on research methods.
At the first meeting, working groups will be assembled and meetings with those will be set up. In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.

Objective
- Understand research methods used in the empirical educational sciences
- Understand and critically examine information from scientific journals and media
- Understand pedagogically relevant findings from the empirical educational sciences

851-0240-22L
Coping with Psychosocial Demands of Teaching (EW4 W DZ)
Number of participants limited to 20.

Abstract
In this class, students will learn concepts and skills for coping with psychosocial demands of teaching.

Objective
Students possess theoretical knowledge and practical competences to be able to cope with the psychosocial demands of teaching.

(1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks).
(2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services).

Subject Didactics and Professional Training
Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Number Title Type ECTS Hours Lecturers
151-1079-00L Teaching Internship Including Examination Lessons 6 credits 13P Q. Lohmeyer

Abstract
The teaching internship can just be visited if all other courses of TC are completed.

Objective
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practice finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content
The students accompany and support the pupil groups of the teacher. Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance. After the internship, the students are able to plan and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.

Lecture notes
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

Literature
Wird von der Praktikumslehrperson bestimmt.

Prerequisites / notice
Alle anderen Lehrveranstaltungen des DZ (inkl. der Mentorierten Arbeit) sind erfolgreich abgeschlossen.

227-0857-00L
Subject Didactics I for D-MAVT and D-ITET

Abstract
Didactics I focuses on teaching techniques as building blocks of typical lessons. This is done on the basis of the findings of teaching and learning research and their implementation in practice. The aim is the planning and implementation of effective teaching sequences as well as their evaluation and reflection.

Objective
- The students can plan, conduct and critically reflect single lessons.
- They orient themselves towards the academic goals and take into account existing knowledge, the professional environment and the ambitions of the students.
- They can apply the basic teaching principles meaningfully in their subject and suitably structure the learning phases.
- They can reduce and present complex technical content such that it is in a form suitable for the students to learn.
- They have considered examples of the common conceptual errors encountered by students.
Content
- Planning a teaching unit
- Opening a lecture
- Direct Instruction
- Blackboard writing and slide design
- Develop exercises
- Practicing teaching
- Excursion Fachhochschule

Lecture notes
Lecture materials are provided via Moodle.

Prerequisites / notice
Prerequisite: Educational science course already completed or at the same time.

Further Subject Didactics
For students enrolled from HS 2019: The courses offered here are credited under the category «Subject Didactics and Professional Training».

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1072-00L</td>
<td>Mentored Thesis in Didactics of Mechanical and Process Engineering</td>
<td>O</td>
<td>2 credits</td>
<td>4A</td>
<td>Q. Lohmeyer</td>
</tr>
</tbody>
</table>

Abstract
The purpose of the mentored thesis is to bring together the findings from didactics and to expand them by incorporating specific teaching techniques and teaching methods. The thesis can be thematically aligned with the subsequent teaching internship.

Objective
The students learn to link theoretical topics from the didactic education with practice-relevant aspects and to articulate the result in written form by means of a suitable task.

Content
The choice of the topic and the definition of the contents takes place in agreement between the students and the mentor. The topic must be chosen in such a way that the learning objective described above can be achieved.

Lecture notes
A short guideline is available.

Literature
The use of suitable literature is part of the assignment.

Prerequisites / notice
Prerequisite: Both didactics courses completed.

The work should be completed before the start of the internship.

Mechanical and Process Engineering TC - Key for Type

<table>
<thead>
<tr>
<th>Key for Hours</th>
<th>Type</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS</th>
<th>European Credit Transfer and Accumulation System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Special students and auditors need special permission from the lecturers.</td>
</tr>
</tbody>
</table>
Materials Science Bachelor
► Bachelor Studies (Programme Regulations 2020)
►► Basis Courses Part I

First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0261-G0L</td>
<td>Analysis I</td>
<td>O</td>
<td>8</td>
<td>5V+3U</td>
<td>A. Steiger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Differential and integral calculus for functions of one and several variables; vector analysis; ordinary differential equations of first and of higher order, systems of ordinary differential equations; power series. The mathematical methods are applied in a large number of examples from mechanics, physics and other areas which are basic to engineering.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Introduction to the mathematical foundations of engineering sciences, as far as concerning differential and integral calculus.</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>U. Stammbach: Analysis I/II</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Exercises and online quizzes are an important aspect of this course. Attempts at solving these problems will be honored with a bonus on the final grade. See &quot;Performance assessment&quot; for more information.</td>
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</tr>
</tbody>
</table>

| 401-0171-00L | Linear Algebra I                     | O    | 3    | 2V+1U  | N. Hungerbühler |
| Abstract    | Linear algebra is an indispensable tool of engineering mathematics. The course offers an introduction into the theory with many applications. The new notions are practised in the accompanying exercise classes. The course will be continued as Linear algebra II. |
| Objective   | Upon completion of this course, students will be able to recognize linear structures, and to solve corresponding problems in theory and practice. |
| Content     | Systems of linear equations, Gaussian elimination, solution space, matrices, LR decomposition, Determinants, structure of linear spaces, normed vector spaces, inner products, method of least squares, QR decomposition, introduction to MATLAB, applications |
* K. Meyberg / P. Vachenauer, Höhere Mathematik 1, Springer 2003 |
| Prerequisites / notice | Active participation in the exercises is part of this course. It is expected, that students submit 3/4 of all exercises for control. |

| 327-0112-00L | Chemistry I                         | O    | 4    | 2V+1U  | M. Niederberger, P. J. Walde, W. R. Caseri |
| Abstract    | Introduction to the basics, terms and concepts of general chemistry, their application to questions in material science and their connection to laboratory experiments and projects. |
| Objective   | 1) Students can describe the different atomic structures of metals, polymers and ceramics and derive basic material-typical properties.  
2) Students are familiar with the concept of mole and molar mass and can perform stoichiometric calculations.  
3) Students are able to formulate the law of mass action and, with the help of the equilibrium constant, make statements about the position of equilibrium. They understand how a chemical equilibrium reacts to changes in concentration, pressure and temperature and how to apply Le Châtelier's principle.  
4) Students can define oxidation and reduction, determine oxidation numbers, assign reducing and oxidizing agents and calculate redox potentials. They can transfer the basics of redox chemistry to material science processes and applications such as corrosion or batteries.  
5) They can explain the terms acid and base, understand what pH means and they can perform pH calculations. They can describe the meaning of acids and bases using material science examples. |
| Content     | We start the lecture with the question what chemistry has to do with material science. After that, we devote ourselves to the classification and separation of substances. In the next chapter we discuss the atomic structure and the periodic table. After the introduction to stoichiometry, the field of chemistry that deals with the amounts of substances added and formed in chemical reactions, we will cover the concept of chemical equilibrium, where we will learn about the law of mass action, equilibrium constants, solubility product, and also acid-base equilibria. In the final block of the lecture, materials science will once again be in the focus when we discuss redox reactions, electrochemistry and corrosion as well as the influence of chemical bonding on material properties. |
| Lecture notes | Lecture slides with references to further literature are available on Moodle. |
| Literature  | German |

| 402-0050-00L | Physics I                           | O    | 4    | 2V+2U  | D. Rupp         |
| Abstract    | The lecture covers the basics of classical mechanics. |
| Objective   | The aim of this lecture is to become familiar with the central concepts of classical mechanics, to test and consolidate basic concepts and physical intuition, and to be able to describe and solve problems with applications from everyday life and technology with the tools learned. |
| Content     | - Inertia, equations of motion, Newton's laws, forces and system boundaries  
- Energy, impulse, rocket launch  
- Central forces, celestial mechanics  
- Tidal/apparent forces, resting and accelerated reference systems  
- Rotational motion  
- Basic properties of deformable bodies  
- Vibrations and resonance phenomena, waves |
| Lecture notes | A script to the lecture is provided online. |

| 327-0113-00L | Foundations of Materials Science I  | O    | 2    | 2G     | L. Isa          |
| Abstract    | The basic physical concepts for the description of materials are taught, partly in self-study, and applied in exercises. Basic atomistic and macroscopic concepts (e.g. phase diagrams, phase transformations, response functions) are introduced through examples. Selected topics are deepened in classroom lectures. |
| Objective   | Students are able to  
- name the basic concepts of materials science. (remember, 1)  
- describe simple relations between atomic structure and macroscopic properties. (understand, 2)  
- calculate basic material-specific quantities. (apply, 3)  
- read and interpret phase diagrams, material characteristic (e.g. stress-strain) diagrams and Ashby plots (analyse, 4) |
| Content     | Atomic structure  
Crystalline structure and defects  
Thermodynamics, phase diagrams and phase transformations  
Diffusion  
Mechanical and thermal properties of materials |
Additional First Year Basic Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-0111-00L</td>
<td>Projects and Lab Courses I</td>
<td>O</td>
<td>7 credits</td>
<td>7P</td>
<td>M. B. Willeke, L. De Pietro, M. R. Dusseiller, S. Morgenthaler Kobas, T.-B. Schweizer</td>
</tr>
</tbody>
</table>

Abstract
Practical introduction to the basics of the scientific method, materials science, physics and chemistry in the form of laboratory experiments and projects, some of which are closely related to the lectures in the first year. Important chemical and physical methods are tested, project work is practiced and the basics of working safely in the laboratory are learned.

Objective
The students
- keep a laboratory journal independently, completely and appropriately.
- can evaluate and display measurement data in a targeted manner.
- are able to write laboratory reports appropriately.
- know the communicative and rhetorical factors that are decisive for the success of an oral presentation.
- create effective presentation documents.
- know the general safety rules and disposal concepts for working in laboratories and apply them practically.
- proceed correctly in case of accidents and evacuations.
- learn practically how to fight a fire (fire protection course of the ETH).
- apply the basic knowledge in analytics, chemistry, physics and materials science acquired in the base year in a practical way.
- practice carrying out small experiments or small projects independently under supervision.

Content
in the area of scientific work: Keeping lab journals, data analysis, writing reports, presentation techniques, Test preparation and introduction to safe working and behaviour in the lab.
Lab experiments: Experiments from the fields of synthetic and analytical chemistry and experiments from the fields of physics and materials science, e.g.: Mechanical/thermal properties (e.g. modulus of elasticity, fracture mechanics), thermodynamics, colloid chemistry, "particle tracking" with DLS and microscopy, surface technology, "wood, stone and metal" processing, and electrochemistry. Some practical experiments are organized as short projects (two afternoons), e.g. "Building a microscope from a webcam", etc.
In the projects: Two "reverse engineering" projects with everyday objects: Analysis of construction and materials, functioning in the overall context, life cycle of materials, alternative materials, etc.

Prerequisites / notice
Special students and auditors need a special permission from the lecturers.

Second Year Basic Courses

Examination Blocks

Analysis III

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-0363-10L</td>
<td>Analysis III</td>
<td>O</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Iozzi</td>
</tr>
</tbody>
</table>

Abstract

Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

Objective

Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

Content

Laplace Transforms:
- Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
- Transforms of Derivatives and Integrals, ODEs
- Unit Step Function, t-Shifting
- Short Impulses, Dirac's Delta Function, Partial Fractions
- Convolution, Integral Equations
- Differentiation and Integration of Transforms

Fourier Series, Integrals and Transforms:
- Fourier Series
- Functions of Any Period p=2L
- Even and Odd Functions, Half-Range Expansions
- Forced Oscillations
- Approximation by Trigonometric Polynomials
- Fourier Integral
- Fourier Cosine and Sine Transform

Partial Differential Equations:
- Basic Concepts
- Modeling: Vibrating String, Wave Equation
- Solution by separation of variables; use of Fourier series
- D'Alembert Solution of Wave Equation, Characteristics
- Heat Equation: Solution by Fourier Series
- Heat Equation: Solutions by Fourier Integrals and Transforms
- Modeling Membrane: Two Dimensional Wave Equation
- Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
- Solution of PDEs by Laplace Transform

Lecture notes

Lecture notes by Prof. Dr. Alessandra Iozzi:
https://polybox.ethz.ch/index.php/s/D3K0TayQXvfpCAA

Literature


For reference/complement of the Analysis I/II courses:

Christian Blatter: Ingenieur-Analysis
https://people.math.ethz.ch/~blatter/dlp.html

327-0316-00L

Quantum Mechanics for Materials Scientists

O 3 credits 2V+1U S. Stepanow

Abstract

Analysis and motivation for the necessity of a theory beyond classical mechanics to describe materials properties. The principles, terminology and concepts of quantum mechanics will be introduced and mathematically represented on the basis of simple problems.

Objective

Give reasons for the necessity of quantum mechanical description of matter and explain experimental observations leading to this description.

Clarification of the term quantum object.

Formulate and solve the Schrödinger equation for simple problems.

Application of the operator formalism for the calculation of observables and the interpretation of physical processes. Interpretation of the wavefunction.

Explain the solution of the hydrogen atom. Derivation of the approach to the solution in the application of symmetries and angular momentum operators.

Give reasons for the electron spin and calculate magnetic moments.
Content

1) The students will be able to recognize different polymer types and associate them with their chemical structure and properties (i.e. T. Lottermoser

2) The students will become familiar with various synthetic methods to produce polymers of different architectures and topologies

3) The students will be exposed to different characterization methods (e.g. size exclusion chromatography, mass-spectrometry, nuclear magnetic resonance) that are necessary to confirm the successful synthesis and structure of a polymer

4) The students will understand the mechanism of selected polymerization methodologies

5) The students will be introduced to state-of-the-art polymer synthesis and recent literature examples will be critically discussed

Objective

- The course teaches the basics and terminology of polymer synthesis. To synthesize various polymeric materials, different polymerization methods are required. This course will introduce representative polymerization methodologies and will discuss how they operate in order to yield materials with enhanced polymeric characteristics.

- The students will be able to recognize different polymer types and associate them with their chemical structure and properties.

- The students will be exposed to different characterization methods necessary to confirm the successful synthesis and structure of a polymer.

- The course provides a solid working knowledge in thermodynamics (as the appropriate language for treating a variety of problems in materials science) and in statistical mechanics (as a systematic tool to find thermodynamic potentials for specific problems).

Abstract

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- The course provides a solid working knowledge in thermodynamics (as the appropriate language for treating a variety of problems in materials science) and in statistical mechanics (as a systematic tool to find thermodynamic potentials for specific problems).

Lecture notes

- Lecture slides with references to further literature will be available on Moodle.

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- Lecture slides with references to further literature will be available on Moodle.

Literature

- J. M. G. Cowie “Polymers: Chemistry and Physics of Modern Materials”


Abstract
The properties of crystals, which represent a large part of solid materials, are closely related to their structural symmetry. The aim of the lecture crystallography is to convey concepts and mathematical basics of symmetry theory, structure-property relationships, as well as the basic features of structure determination. Simple crystal structure types are discussed.

Objective
Introduction into the fundamental relationships between crystal structure, symmetry, and physical properties of solids. Emphasis: group-theoretical introduction into symmetry, discussion of the factors governing the formation of crystal structures, structural dependence of physical properties, fundamentals of experimental techniques probing the crystal structure.

Content
Symmetry and order: symmetry operations and lattices in two and three dimensions, point groups, space groups.

Crystal structures: symmetry and geometrical factors governing the formation of crystal structures; close sphere packings; typical basic crystal structures.

Structure/property relationships: Neumann's principle; examples: piezoelectricity, ferroelectricity.

Materials characterization: diffraction techniques.

Literature

Prerequisites

Organisation: One hour of lectures per week accompanied by one hour of exercises.

Projects and Applications

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-0314-00L</td>
<td>Computational Thinking Lab I</td>
<td>O</td>
<td>2</td>
<td>1G</td>
<td>M. Kröger</td>
</tr>
</tbody>
</table>

Abstract
You are going to address, in groups, problems that are arising or may arise in the context of remaining courses of your studies, that cannot be solved analytically or manually within reasonable amounts of time, but solved computationally with the help of a programming language and computers. Knowledge of a computing language is required.

Objective
Students get used to one or more collaborative tools, work actively in groups. They invent, set up, structure, plan, and attempt solving a problem that requires developing algorithms. They make use of existing, or invent novel, computational methods. Aspects that should be taken into account when developing algorithms or codes are: speed of execution, ease of use, small amount of adjustable parameters.

Content
Development of a project plan, including modules to be created, milestones to be reached, required input data and its acquisition, tests to be performed, work sharing. The project needs to be documented, and codes saved using a collaborative environment (overleaf). Ideally, several groups attack a similar problem so that their results can be directly compared (concerning speed of execution, clarity etc.)

Lecture notes
A script of the lecture until 2014 is available. Script notes for the present lecture will be provided before the start of the lecture.

Literature


Prerequisites
Knowledge of a programming language is mandatory. Participants need to create an overview account. Detailed information available at Information available at https://polyphys.mat.ethz.ch/education/courses/CTL-I.html

Prerequisites

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
assessed

Domain B - Method-specific Competencies
Analytical Competencies
assessed
Decision-making
assessed
Media and Digital Technologies
assessed

Domain C - Social Competencies
Communication
assessed

Domain D - Personal Competencies
Negotiation
assessed
Adaptability and Flexibility
assessed

Projects and Lab Courses III

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-0311-00L</td>
<td>Projects and Lab Courses III</td>
<td>O</td>
<td>8</td>
<td>8P</td>
<td>M. B. Willeke, L. De Pietro, T.-B. Schweizer</td>
</tr>
</tbody>
</table>

Abstract
A project lasting one semester, with special requirements regarding choice of materials, properties, etc., concluding project presentation event.

Experiments to teach experimental competence using selected examples from polymer chemistry, analytics and physics (e.g. for the storage or conversion of energy), partly closely based on courses.

Objective
Learn how to organize, manage, and execute a semester-long project.

To impart basic knowledge and experimental competence using selected examples from chemistry and physics.

Content
Semester-long project, project assignment is determined at the beginning of each semester.

Chemistry III: Synthesis of PMMA via Transesterification; PET recycling or manufacture of poly(methylmethacrylat) via radical polymerization of methylmethacrylat; 3D-printing.

Physics I: five experiments out of: reflection spectroscopy, experiments on the field of polyers, e.g. viscoelasticity of the polymer melt (or an equivalent exp.), 2 physics experiments (out of 4) at the EMPA: e.g. X-ray fluorescence analysis, impedance measurements of batteries, “power to gas” or texture measurement, building a Lithium ionic battery; and further physic experiments.

Lecture notes
Notes with information for each experiment (aim of the experiment, theory, experimental procedure, data analysis) can be downloaded from the web (https://praktikum.mat.ethz.ch or https://www.mat.ethz.ch/studies/bachelor/laborpraktische-ausbildung.html).
Knowledge of the basic principles of probability theory and statistics.

ECTS

Type

Script will be for the production price

3G


Introduction to partial differential equations. Differential equations which are important in applications are classified and solved. Elliptic, parabolic and hyperbolic differential equations are treated. The following mathematical tools are introduced: Laplace transforms, Fourier series, separation of variables, methods of characteristics.

Prerequisites / notice

Excercises are integrated in the lectures. In addition, attendance in the lecture 529-0289-00 "Instrumental analysis of organic compounds" (4th semester) is recommended.

The further courses of the examination block 1, regl. 2017 (327-0309-00L Organic Chemistry in Materials Science, 402-0041-00L Physics, 551-0015-00L Biology I) were offered for the last time in HS20.

The further course of the examination block 2, regl. 2017 (327-0308-00L Programming Techniques in Materials Science) was offered for the last time in HS20.
Simulation Techniques that are relevant for material science. Simulation methods for continua (finite differences, finite elements), mesoscopic methods (cellular automata, mesoscopic Monte Carlo methods), microscopic methods (Molecular Dynamics, Monte-Carlo simulations, Density Functional Theory).

Objective
- Learn how to organize, manage, and execute a semester-long project.
- Learn to impart basic knowledge and experimental competence using selected examples from chemistry and physics.

Content
- Semester-long project, project assignment is determined at the beginning of each semester.
- Chemistry III: Synthesis of PMMA via Transesterification; PET recycling or manufacture of poly(methylmethacrylat) via radical polymerization of methylmethacrylat; 3D-printing.
- Physics I: five experiments out of: reflection spectroscopy, experiments on the field of poliers, e.g. viscoelasticity of the polymer melt (or an equivalent exp.), 2 physics experiments (out of 4) at the EMPA: e.g. X-ray floccence analysis, impediment measurements of batteries, “power to gas” or texture measurement, building a Lithium ionic battery; and further physics experiments.

Lecture notes
- Notes with information for each experiment (aim of the experiment, theory, experimental procedure, data analysis) can be downloaded from the web (https://praktikum.mat.ethz.ch or https://www.mat.ethz.ch/studies/bachelor/laborpraktische-ausbildung.html).

Prerequisites / notice

Additional Basic Courses

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-0311-00L</td>
<td>Projects and Lab Courses III</td>
<td>O</td>
<td>8</td>
<td>8P</td>
<td>M. B. Willeke, L. De Pietro, T.-B. Schweizer</td>
</tr>
</tbody>
</table>

Materials Characterisation Methods

Offered for the last time in HS 2021.

Abstract
- The lecture course is aimed at qualifying the student to choose the optimum characterization method according to the questions posed.

Objective
- The lecture course is aimed at qualifying the student to choose the optimum characterization method according to the questions posed.

Content
- Introduction into the fundamentals of materials characterization: Thermal Analysis (TD, TG, TM, DTA, DSC), light microscopy, diffraction methods (XRD, NRD, SAD), electron microscopy (TEM, HRTEM, STEM, HAADF-STEM, SEM, ESEM, EFEM, EDX, EELS).

Materials Physics I

Offered for the last time in HS 2021.

Abstract
- This course introduces classical and quantum mechanical concepts for the understanding of material properties from a microscopic point of view. The lectures focus on the static and dynamic properties of crystals, the formation of chemical bonds and electronic bands in metals, and semiconductors, and on the thermal and electrical properties that emerge from this analysis.
Objective

Providing physical concepts for the understanding of material properties:

Understanding the electronic properties of solids is at the heart of modern society and technology. The aim of this course is to provide fundamental concepts that allow the student to relate the microscopic structure of matter and the quantum mechanical behavior of electrons to the macroscopic properties of materials. Beyond fundamental curiosity, such level of understanding is required in order to develop and appropriately describe new classes of materials for future technology applications. By the end of the course the student should have developed a semi-quantitative understanding of basic concepts in solid state physics and be able to appreciate the pertinence of different models to the description of specific material properties.

Content

PART I: Structure of solid matter, real and reciprocal space

The crystal lattice, Bravais lattices, primitive cells and unit cells, Wigner-Seitz cell, primitive lattice vectors, lattice with a basis, examples of 3D and 2D lattices.

Fourier transforms and reciprocal space, reciprocal lattice vectors, Brillouin zones

Elastic and inelastic scattering of elementary particles with matter (x-rays, neutrons, electrons). Interaction of x-rays with matter. X-ray diffraction, Bragg condition, atomic scattering factors, scattering length, absorption and refraction

PART II: Dynamics of atoms in crystals

Lattice vibrations and phonons in 1D, phonons in 1D chains with monoatomic basis, phonon in 1D chains with a diatomic basis, optical and acoustic modes, phase and group velocities, phonon dispersion and eigenvectors. Phonons in 2D and 3D.

Quantum mechanical description of lattice waves in solids, the harmonic oscillator, the concept of phonon, phonon statistics, Bose-Einstein distribution, phonon density of states, Debye and Einstein models, thermal energy, heat capacity of solids.

PART III: Electron states and energy bands in crystalline solids

Electronic properties of materials, classical concepts: electrical conductivity, Hall effect, thermoelectric effects. Drude model. Transition to quantum models and review of quantum mechanical concepts.

The formation of electronic bands: from molecules to periodic crystal structures.

The free electron gas: Fermi statistics, Fermi energy and Fermi surface, density of states in k-space and as a function of energy. Inadequacy of the free electron model.


PART IV: Electrical and heat conduction

Dynamics of electrons in energy bands, phase and group velocity, crystal momentum, the effective mass concept, scattering phenomena.

Electrical and thermal conductions revisited. Electron transport due to electric fields (drift) and concentration gradients (diffusion). Einstein's relations. Transport of heat by electrons, Seebeck effect and thermopower, Peltier effect, thermoelectric cooling, thermoelectric energy conversion.

PART V: Semiconductors: concepts and devices


Discrete and continuous spectrum of energy states, fermi level, fermi distribution function, degeneracy, filling of bands.


Inadequacy of the free electron model.

The free electron gas: Fermi statistics, Fermi energy and Fermi surface, density of states in k-space and as a function of energy. Inadequacy of the free electron model.


Electronic properties of materials, classical concepts: electrical conductivity, Hall effect, thermoelectric effects. Drude model. Transition to quantum models and review of quantum mechanical concepts.

The formation of electronic bands: from molecules to periodic crystal structures.

The free electron gas: Fermi statistics, Fermi energy and Fermi surface, density of states in k-space and as a function of energy. Inadequacy of the free electron model.

Content
Dislocation theory:
- Properties of dislocations, motion and kinetics of dislocations, dislocation-dislocation and dislocation-boundary interactions, consequences of partial dislocations, sessile dislocations

Hardening theory:
- a. solid solution hardening: case studies in copper-nickel and iron-carbon alloys
- b. particle hardening: case studies on aluminium-copper alloys

High temperature plasticity:
- thermally activated glide
- power-law creep
- diffusion creep: Coble, Nabarro-Herring
- deformation mechanism maps
- Case studies in turbine blades
- superplasticity
- alloying effects

Literature
- Gottstein, Physikalische Grundlagen der Materialkunde, Springer Verlag
- Haasen, Physikalische Metallkunde, Springer Verlag
- Rösler/Harders/Bäker, Mechanisches Verhalten der Werkstoffe, Teubner Verlag
- Porter/Easterling, Transformations in Metals and Alloys, Chapman & Hall
- Hull/Bacon, Introduction to Dislocations, Butterworth & Heinemann
- Courtney, Mechanical Behaviour of Materials, McGraw-Hill

327-0502-00L Polymers I O 3 credits 2V+1U M. Kröger
Offered for the last time in HS 2021.

Abstract
Physical foundations of single polymer molecules and interacting chains.

Objective
The course offers a modern approach to the understanding of universal static and dynamic properties of polymers.

Content
Polymer Physics:
1. Introduction to Polymer Physics, Random Walks
2. Excluded Volume
3. Structure Factor from Scattering Experiments
4. Persistence
5. Solvent and Temperature Effects
6. Flory theory
7. Self-consistent field theory
8. Interacting Chains, Phase Separation and Critical Phenomena
9. Rheology
10. Numerical methods in polymer physics, computer experiments

Literature

327-0503-00L Ceramics I O 3 credits 2V+1U M. Niederberger, A. Demirörs, T. Graule
Offered for the last time in HS 2021.

Abstract
Introduction to ceramic processing.

Objective
The aim is the understanding of basic principles of ceramic processing.

Content
Basic chemical processes for powder production.
Liquid-phase synthesis methods.
Sol-Gel processes.
Classical crystallization theory.
Gas phase reactions.
Basics of the colloidal chemistry for suspension preparation and control.
Characterization techniques for powders and colloids.
Shaping techniques for bulk components and thin films.
Sintering processes and microstructural control.

Literature
Books and references will be given on the lecture notes.

327-2131-00L Materials of Life O 3 credits 3G E. Dufresne
Offered for the last time in HS 2021.

Abstract
This course examines the materials underlying living systems. We will consider the basic building blocks of biological systems, the processes which organize them, the resulting structures, their properties and functions.

Objective
Students will apply basic materials science concepts in a new context while deepening their knowledge of biology. Emphasis on estimating key physical quantities through 'back of the envelope' estimates and simple numerical calculations.

Content
I. Biology Essentials
   - Water: the solvent of life
II. Metabolism and Macromolecular Machines
   - Fundamentals of macromolecular assembly
V. Structure, properties, and function of living materials:
   - 1-D materials
     - Cytoskeletal filaments
   - 2-D materials
     - Lipid membranes
   - 3-D materials
     - Polymer networks
   - Phase separated domains

Lecture notes
Lecture notes will be available for download after each lecture.

>>> Basic Courses Part 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>327-0511-00L</td>
<td>Practical Course V</td>
<td>O</td>
<td>6</td>
<td>8P</td>
<td>M. B. Willeke, J. F. Löffler</td>
</tr>
</tbody>
</table>

Abstract
Acquisition of independent scientific-technical skills; project management; organization and undertaking of experiments; interpretation, scientifically and technically correct project presentation in oral and written form.

Objective
Acquisition of independent scientific/technical skills; project management; organization and conducting of experiments; interpretation and scientifically/technically correct presentation of projects in oral and written form.

Content
Supervision by D-MATL research Groups.
Groups of students (2 or 3 per group) each work on a research project throughout the semester.

Prerequisites / notice
Prerequisite: Successful participation in the "Praktika I - IV" (courses within the material science bachelor study at ETH) or comparable practical lab courses.

Compensatory Courses
Only possible after consultation with the Director of Studies.

Industrial Internship or Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>327-0001-00L</td>
<td>Industrial Internship</td>
<td>W</td>
<td>10 credits</td>
<td></td>
<td>external organisers</td>
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<tr>
<td></td>
<td>Only for Materials Science BSc.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>12 weeks of industrial internship which is completed with a written report.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The main objective of the 12-week internship is to expose bachelor's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.</td>
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<td>Carrying out outside of D-MATL: Only possible after consultation with the Director of Studies.</td>
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<tr>
<td>Abstract</td>
<td>Project in a research group at ETH or at an University of 12 weeks. The project is completed with a written report.</td>
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<tr>
<td>Objective</td>
<td>The main objective of the 12-week research project is to expose bachelor's students to the professional research environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.</td>
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Bachelor’s Thesis

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>327-0620-00L</td>
<td>Bachelor’s Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>17D</td>
<td>Professors</td>
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<td></td>
<td>Only for Materials Science BSc Programme Regulations 2017.</td>
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<tr>
<td>Abstract</td>
<td>Independent scientific project in a D-MATL research group. A written report will be prepared on the scientific studies carried out, as well as on the evaluation and discussion of the results.</td>
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<tr>
<td>Objective</td>
<td>To develop the capability of independently analyzing and addressing scientific problems.</td>
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<tr>
<td>Content</td>
<td>Independent work on a scientific research project. The project will be carried out either for two days per week during the 6th semester or in a block within the first 6 weeks after the 6th semester.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The entire project, including preparation of the report, needs to take place within the allotted time.</td>
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GESS Science in Perspective

Science in Perspective
Recommended GESS Science in Perspective (Type B) for D-MATL.

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Language Courses
see GESS Science in Perspective: Language Courses ETH/UZH

Materials Science Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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Key for Hours

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<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-0505-00L</td>
<td>Surfaces, Interfaces and their Applications I</td>
<td>W</td>
<td>3 credits</td>
<td>2+1U</td>
<td>N. Spencer, M. P. Heuberger, L. Isa</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>After being introduced to the physical/chemical principles and importance of surfaces and interfaces, the student is introduced to the most important techniques that can be used to characterize surfaces. Later, liquid interfaces are treated, followed by an introduction to the fields of tribology (friction, lubrication, and wear) and corrosion.</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>To gain an understanding of the physical and chemical principles, as well as the tools and applications of surface science, and to be able to choose appropriate surface-analytical approaches for solving problems.</td>
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<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Introduction to Surface Science</td>
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<td></td>
<td>Physical Structure of Surfaces</td>
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<td>Surface Forces (static and dynamic)</td>
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<td>Adsorbates on Surfaces</td>
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<td></td>
<td>Surface Thermodynamics and Kinetics</td>
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<td>The Solid-Liquid Interface</td>
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<td></td>
<td>Electron Spectroscopy</td>
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<td></td>
<td>Vibrational Spectroscopy on Surfaces</td>
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<td></td>
<td>Scanning Probe Microscopy</td>
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<td></td>
<td>Introduction to Tribology</td>
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<td></td>
<td>Introduction to Corrosion Science</td>
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<td>Lecture notes</td>
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<td>Script Download:</td>
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<td><a href="https://moodle-app2.let.ethz.ch/course/view.php?id=14993">https://moodle-app2.let.ethz.ch/course/view.php?id=14993</a></td>
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<td>327-1201-00L</td>
<td>Transport Phenomena I</td>
<td>W Dr</td>
<td>5 credits</td>
<td>4G</td>
<td>J. Vermant</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Phenomenological approach to “Transport Phenomena” based on balance equations supplemented by thermodynamic considerations to formulate the undetermined fluxes in the local species mass, momentum, and energy balance equations; Solutions of a few selected problems relevant to materials science and engineering both analytical and using numerical methods.</td>
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<td>Objective</td>
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<td></td>
<td>The teaching goals of this course are on five different levels:</td>
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<td></td>
<td>(1) Deep understanding of fundamentals: local balance equations, constitutive equations for fluxes, entropy balance, interfaces, idea of dimensionless numbers and scaling, ...</td>
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<td>(2) Ability to use the fundamental concepts in applications</td>
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<td>(3) Insight into the role of boundary conditions (mainly part 2)</td>
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<td>(4) Knowledge of a number of applications.</td>
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<td>(5) Flavor of numerical techniques: finite elements and finite differences.</td>
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<td></td>
<td>Content</td>
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<td></td>
<td>Part 1 Approach to Transport Phenomena</td>
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<td>Equilibrium Thermodynamics</td>
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<td>Balance Equations</td>
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<td>Forces and Fluxes</td>
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<td>Applications</td>
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<td>1. Measuring Transport Coefficients</td>
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<td>2. Fluid mechanics</td>
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<td>3. combined heat and flow</td>
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<td>Lecture notes</td>
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<td>Literature</td>
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<td>Prerequisites / notice</td>
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<td>Physics: General undergraduate chemistry</td>
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<td>including basic chemical kinetics and thermodynamics</td>
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<td>Taught competencies</td>
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<td></td>
<td>Domain A - Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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<td>Domain B - Method-specific Competencies</td>
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<td></td>
<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
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<td></td>
<td>Problem-solving</td>
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<td>Domain D - Personal Competencies</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
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<tr>
<td>327-1202-00L</td>
<td>Solid State Physics and Chemistry of Materials I</td>
<td>W Dr</td>
<td>5 credits</td>
<td>4G</td>
<td>N. Spaldin</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>In this course we study how the properties of solids are determined from the chemistry and arrangement of the constituent atoms, with a focus on materials that are not well described by conventional band theories because their behavior is governed by strong quantum-mechanical interactions.</td>
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<td>Objective</td>
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<td>The course on solid state physics and chemistry of materials is based on the advanced undergraduate text Solid State Physics by Sen and Basu. The course also uses the book by Ziman. The course is part of the Materials Science Master program and is intended to provide a foundation in the physics of materials.</td>
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<td>Content</td>
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<td></td>
<td>Taught competencies</td>
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<td></td>
<td>Domain A - Subject-specific Competencies</td>
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<td></td>
<td>Concepts and Theories</td>
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<td>assessed</td>
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<td></td>
<td>Techniques and Technologies</td>
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<td>assessed</td>
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<td></td>
<td>Domain B - Method-specific Competencies</td>
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<td></td>
<td>Problem-solving</td>
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<td>assessed</td>
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</table>
In this course we study how the properties of solids are determined from the chemistry and arrangement of the constituent atoms, with a focus on materials that are not well described by conventional band theories because their behavior is governed by strong quantum-mechanical interactions. We begin with a review of the successes of band theory in describing many properties of metals, semiconductors and insulators, and we practise building up band structures from atoms and describing the resulting properties. Then we explore classes of systems in which the coupling between the electrons and the lattice is so strong that it drives structural distortions such as Peierls instabilities, Jahn-Teller distortions, and ferroelectric transitions. Next, we move on to strong couplings between electronic charge and spin-and/or orbital- angular momentum, yielding materials with novel magnetic properties. We end with examples of the complete breakdown of single-particle band theory in so-called strongly correlated materials, which comprise for example heavy-fermion materials, frustrated magnets, materials with unusual metal-insulator transitions and the high-temperature superconductors.

Teaching goals:

- to learn how to design and create objects as building blocks with a particular composition, size and shape,
- to understand the chemistry that allows for the creation of such hard and soft objects, and
- to master the concepts to assemble these objects into materials over several length scales.

Content

The course is divided into two parts: I) synthesis of 0-, 1-, 2-, and 3-dimensional building blocks with a length scale from nm to μm, and II) assembly of these building blocks into 1-, 2- and 3-dimensional structures over several length scales up to cm. In part I, various methodologies for the synthesis of the building blocks will be discussed, including Turkevich and Brust-Schiffrin-method for gold nanoparticles, hot-injection for semiconducting quantum dots, aqueous and nonaqueous sol-gel chemistry for metal oxides, or gas- and liquid-phase routes to carbon nanostructures.

Part II is focused on self- and directed assembly methods that can be used to create higher order architectures from those building blocks connecting the microscopic with the macroscopic world. Examples include photonic crystals, nanocrystal solids, colloidal molecules, mesocrystals or particle-based foams and aerogels.

Abstract

Introduction to materials synthesis concepts based on the assembly of differently shaped objects of varying chemical nature and length scales. The aim is a) to learn how to design and create objects as building blocks with a particular composition, size and shape, b) to understand the chemistry that allows for the creation of such hard and soft objects, and c) to master the concepts to assemble these objects into materials over several length scales.

Objective

327-1203-00L

Complex Materials I: Synthesis & Assembly

W Dr 5 credits 4G M. Niederberger, A. Lauria

Objective

- to learn how to design and create objects as building blocks with a particular composition, size and shape,
- to understand the chemistry that allows for the creation of such hard and soft objects, and
- to master the concepts to assemble these objects into materials over several length scales.

Content

The course is divided into two parts: I) synthesis of 0-, 1-, 2-, and 3-dimensional building blocks with a length scale from nm to μm, and II) assembly of these building blocks into 1-, 2- and 3-dimensional structures over several length scales up to cm. In part I, various methodologies for the synthesis of the building blocks will be discussed, including Turkevich and Brust-Schiffrin-method for gold nanoparticles, hot-injection for semiconducting quantum dots, aqueous and nonaqueous sol-gel chemistry for metal oxides, or gas- and liquid-phase routes to carbon nanostructures.

Part II is focused on self- and directed assembly methods that can be used to create higher order architectures from those building blocks connecting the microscopic with the macroscopic world. Examples include photonic crystals, nanocrystal solids, colloidal molecules, mesocrystals or particle-based foams and aerogels.

Abstract

Introduction to materials synthesis concepts based on the assembly of differently shaped objects of varying chemical nature and length scales. The aim is a) to learn how to design and create objects as building blocks with a particular composition, size and shape, b) to understand the chemistry that allows for the creation of such hard and soft objects, and c) to master the concepts to assemble these objects into materials over several length scales.

Objective

- to learn how to design and create objects as building blocks with a particular composition, size and shape,
- to understand the chemistry that allows for the creation of such hard and soft objects, and
- to master the concepts to assemble these objects into materials over several length scales.

Content

The course is divided into two parts: I) synthesis of 0-, 1-, 2-, and 3-dimensional building blocks with a length scale from nm to μm, and II) assembly of these building blocks into 1-, 2- and 3-dimensional structures over several length scales up to cm. In part I, various methodologies for the synthesis of the building blocks will be discussed, including Turkevich and Brust-Schiffrin-method for gold nanoparticles, hot-injection for semiconducting quantum dots, aqueous and nonaqueous sol-gel chemistry for metal oxides, or gas- and liquid-phase routes to carbon nanostructures.

Part II is focused on self- and directed assembly methods that can be used to create higher order architectures from those building blocks connecting the microscopic with the macroscopic world. Examples include photonic crystals, nanocrystal solids, colloidal molecules, mesocrystals or particle-based foams and aerogels.
Elective Courses

The students are free to choose individually from the entire course offer of ETH Zürich on the Master level. Please consult the study administration in case of questions.

### 327-1207-00L Engineering with Soft Materials

**W Dr** 5 credits 4G J. Vermant, L. Isa

**Abstract**
In this course the engineering with soft materials is discussed. First, scaling principles to design structural and functional properties are introduced. Second, the characterization techniques to interrogate the structure property relations are introduced, which include rheology, advanced optical microscopies, static and dynamic scattering and techniques for liquid interfaces.

**Objective**
The learning goals of the course are to introduce the students to soft matter and its technological applications, to see how the structure property relations depend on fundamental formulation properties and processing steps. Students should also be able to select a measurement technique to evaluate the properties.

**Lecture notes**
Slides with text notes accompanying each slide are presented.

### 327-0702-00L EM-Practical Course in Materials Science

**W** 2 credits 4P K. Kunze, S. Gerstl, F. Gramm, F. Krumeich, J. Reuteler

**Abstract**
Practical work on TEM, SEM, FIB and APT treatment of typical problems data analysis, writing of a report

**Objective**
Application of basic electron microscopic techniques to materials science problems

**Literature**
see lecture Electron Microscopy (327-0703-00L)

**Prerequisites / notice**
Attendance of lecture Electron Microscopy (327-0703-00L) is recommended.

**Maximum number of participants 15, work in groups of 3 people.**

### 327-0703-00L Electron Microscopy in Material Science


**Abstract**
A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

**Objective**
A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

**Content**
This course provides a general introduction into electron microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, recent applications in materials science, solid state physics, structural biology, structural geology and structural chemistry will be reported.

**Lecture notes**
will be distributed in English

**Literature**


Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)

### 327-1101-00L Biomineralization

**W** 2 credits 2V K.-H. Ernst

**Abstract**
The course addresses undergraduate and graduate students interested in getting introduced into the basic concepts of biomineralization.

**Objective**
The course aims to introduce the basic concepts of biomineralization and the underlying principles, such as supersaturation, nucleation and growth of minerals, the interaction of biominerals with mineral surfaces, and cell biology of inorganic materials creation. An important part of this class is the independent study and the presentation of original literature from the field.

**Content**
Biomineralization is a multidisciplinary field. Topics dealing with biology, molecular and cell biology, solid state physics, mineralogy, crystallography, organic and physical chemistry, biochemistry, dentistry, oceanography, geology, etc. are addressed. The course covers definition and general concepts of biomineralization (BM) types of biominerals and their function / crystal nucleation and growth / biological induction of BM / control of crystal morphology, habit, shape and orientation by organisms / strategies of compartmentalization / the interface between biopolymers (peptides, polysaccharides) and the mineral phase / modern experimental methods for studying BM phenomena / inter-, intra, extra- and epicellular BM / organic templates and matrices for BM / a. vertebrates and invertebrates and mollusk shells / calcification / sification in diatoms, radiolaria and plants / calcium and iron storage / impact of BM on lithosphere and atmosphere / evolution / taxonomy of organisms.

1. Introduction and overview
2. Biominerals and their functions
3. Chemical control of biomineralization
4. Control of morphology: Organic templates and additives
5. Modern methods of investigation of BM
6. BM in matrices: bone and nacre
7. Vertebrate teeth
8. Invertebrate teeth
9. BM within vesicles: calcite of coccoliths
10. Silica
11. Iron storage and mineralization

**Lecture notes**
Script with more than 600 pages with many illustrations will be distributed free of charge.

**Literature**
3) P. M. Dove, J. J. DeYoreo, S. Weiner (Eds.) Biomineralization, Reviews in Mineralogy & Geochemistry Vol. 54, 2003

**Prerequisites / notice**
No special requirements are needed for attending. Basic knowledge in chemistry and cell biology is expected.

### 327-1221-00L Biological and Bio-Inspired Materials

**W Dr** 4 credits 3G A. R. Studart, I. Burgert, R. Nicolosi Libanori, G. Panzarasa

**Students that already enrolled in this course during their Bachelor's degree studies are not allowed to enrol again in their Master's.**

**Abstract**
The aim of this course is to impart knowledge on the underlying principles governing the design of biological materials and on strategies to fabricate synthetic model systems whose structural organization resembles those of natural materials.

**Objective**
The course first offers a comprehensive introduction to evolutive aspects of materials design in nature and a general overview about the most common biopolymers and biominerals found in biological materials. Next, current approaches to fabricate bio-inspired materials are presented, followed by a detailed evaluation of their structure-property relationships with focus on mechanical, optical, surface and adaptive properties.
This course is structured in 3 blocks:
Block (I): Fundamentals of engineering in biological materials
- Biological engineering principles
- Basic building blocks found in biological materials

Block (II): Replicating biological design principles in synthetic materials
- Biological and bio-inspired materials: polymer-reinforced and ceramic-toughened composites
- Lightweight biological and bio-inspired materials
- Functional biological and bio-inspired materials: surfaces, self-healing and adaptive materials

Block (III): Bio-inspired design and systems
- Mechanical actuation - plant systems
- Bio-inspiration in the built environment

The course is mainly based on the books listed below. Additional references will be provided during the lectures.


Copies of the slides will be made available for download before each lecture.

The selected applicants will be contacted and asked for additional information that will be given during the lectures.

The course will comprise a balance of lectures, tutorial discussions, student presentations and laboratory classes. In addition, case study site visits will be organized to illustrate the industrial application of particular technologies.

More and more, the interest in particle and fibre reinforced / structural composite material systems is increasing. In beginning, the main focus will be on the production of functional fibres, e.g., for fibre-based sensor and actuator composites with polymers, metals and ceramics. Optical, piezoelectric, shape memory and other fibres for advanced composite applications will be treated in detail. There will be a discussion on fibre classification, fibre production (ceramic and others), adaptive and smart materials, types of sensors and actuators (e.g. made from electro-active polymers), and sensor networks with piezoelectric composites (e.g. Active or Macro Fibre Composites) for adaptive material systems or structural health monitoring (SHM) of advanced composite structures. Furthermore, students will get an overview of biomedical composites and composite application in the field of aerospace, automotive, civil engineering, and energy industry.

Emphasis will be put on the underlaying science of a particular process or effect rather than a detailed description of the technique or equipment.

Manufacturing of actuators driven by electro-active polymers (EAP) and sensors applications of Active Fibre Composites (AFC) will be studied in laboratory classes.

Case studies and examples drawn from structural and functional applications of advanced composite and adaptive material systems will be demonstrated.

Lecture notes will be distributed


Adaptronics and smart structures : basics, materials, design, and applications by H. Janocha. Publisher: Springer 1999; Berlin, New York.


Prerequisites / notice


Prerequisite: ETH-course 327-0610 Composite Materials or similar course

This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.
Objective

- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content

During the course, students learn through lectures, demonstrations, and hands-on sessions how to set-up and operate SEM instruments, including low-vacuum and low-voltage applications. This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecture notes
Lecture notes will be distributed.

Literature


Prerequisites / notice

No mandatory prerequisites.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>327-2126-00L</td>
<td>Microscopy Training TEM I - Introduction to TEM</td>
<td>2</td>
<td>SP</td>
<td>No mandatory prerequisites.</td>
</tr>
<tr>
<td>327-2127-00L</td>
<td>Sustainable Materials Management: Concepts, Methods and Principles</td>
<td>2</td>
<td>1V+1U</td>
<td>P. Wäger, R. Widmer</td>
</tr>
</tbody>
</table>

Abstract

The aim of this course is to introduce important concepts, methods and principles for sustainable materials management and to critically reflect their possibilities and limitations. A particular focus will be laid on recycling issues. Students develop a basic understanding of important concepts, methods and principles for sustainable materials management and become acquainted with their possibilities and limitations.
The course consists of six lectures introducing concepts, methods and principles for a sustainable materials management (including, amongst others, material flow analysis, life cycle assessment, raw materials criticality evaluation), with a particular focus on recycling issues and exemplifications for materials relevant for Information and Communication Technologies (ICT) and emerging energy technologies.


Limited number of participants.

More information here: https://scopem.ethz.ch/education/MTP.html

Abstract
This advanced course on High Resolution Transmission Electron Microscopy (HRTEM) provides lectures focused on HRTEM and HRSTEM imaging principles, related data analysis and simulation and phase restoration methods.

Objective
- Learning how HRTEM and HRSTEM images are obtained.
- Learning about the aberrations affecting the resolution in TEM and STEM and the different methods to correct them.
- Learning about TEM and STEM images simulation software.
- Performing TEM and STEM image analysis (processing of TEM images and phase restoration after focal series acquisitions).

Content
This course provides new skills to students with previous TEM experience. At the end of the course, students will know how to obtain HR(STEM) images, how to analyse, process and simulate them.

Topics:
1. Introduction to HRTEM and HRSTEM
2. Considerations on (S)TEM instrumentation for high resolution imaging
3. Lectures on aberrations, aberration correction and aberration corrected images
4. HRTEM and HRSTEM simulation
5. Data analysis, phase restoration and lattice-strain analysis

Literature
- Detailed course manual

Prerequisites / notice
The students should fulfil one or more of these prerequisites:
- Prior attendance to ETH EM lectures (327-0703-00L Electron Microscopy in Material Science)
- Prior TEM experience

327-2129-00L Analytical Electron Microscopy: EDS W 1 credit 2P

Does not take place this semester.

Abstract
The main goal of this hands-on course is to provide students with fundamental understanding of underlying physical processes, experimental set-up solutions and hands-on practical experience of analytical electron microscopy (AEM) technique for microstructure characterisation, specifically Energy Dispersive X-ray Spectroscopy (EDS) and spectrum imaging (SI) technique.

Objective
- Understanding of physical processes that enable the EDS technique and data evaluation algorithms;
- Hands-on experience of data acquisition and evaluation routines including:
  - Practical understanding of different data acquisition set-ups,
  - Optimization of acquisition parameters for most reliable quantification of the results,
  - Knowledge of the available and most reliable quantification algorithms and their handling,
  - Knowledge of data evaluation routines and possible handicaps for reliable elemental content distribution analyses and material composition quantification.
- The effect of the specimen geometry on the data and experimental solutions for minimization of the artefacts

Content
This advanced course provides analytical EM techniques to the students with prior EM experience (TEM or SEM). At the end of the course, students will understand the physical processes that enable the EDS technique and data evaluation algorithms and apply the technique for their own research.

- Introduction to analytical electron microscopy: theory and instrumentation.
- Lectures on EDS, WDS
- Practical on EDS-SEM: data acquisition and analysis.
- Practical on EDS-TEM: data acquisition and analysis.

The hand-on trainings are to be carried-out on a real-life specimen, provided by lecturers and / by students.

Lecture notes
Provided in the course Moodle-page

Literature
- Carter & Williams: Transmission Electron Microscopy: Diffraction, Imaging and Spectrometry, Springer Verlag, 2016, DOI: 10.1007/978-3-319-26651-0

Prerequisites / notice
- Master student or PhD student who has experience with EM (SEM or TEM) techniques or prior attendance of one of the following courses: Microscopy Training SEM1 (327-2125-00L) or Microscopy Training TEM1 (327-2126-00L)
- Attendance of the following courses is of advantage, but not required: Scattering Techniques for Material Characterization (327-2137-00L) or Elements of Microscopy (227-0390-00L) or Electron Microscopy in Material Science (327-0703-00L)

327-2132-00L Multifunctional Ferroic Materials: Growth and Characterisation W 2 credits 2G M. Trassin

Abstract
The course will explore the growth of (multi-) ferroic oxide thin films. The structural characterization and ferroic state investigation by force microscopy and by laser-optical techniques will be addressed. Oxide electronics device concepts will be discussed.

Objective
Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up the whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal. Particularly interesting phenomena occur in films showing magnetic or electric order or, even better, both of these ("multiferroics").

In this course students will obtain an overarching view on oxide thin epitaxial films and heterostructures design, reaching from their growth by pulsed laser deposition to an understanding of their magnetoelectric functionality from advanced characterization techniques. Students will therefore understand how to fabricate and characterize highly oriented films with magnetic and electric properties not found in nature.

Content
Types of ferroic order, multiferroics, oxide materials, thin-film growth by pulsed laser deposition, molecular beam epitaxy, RF sputtering, structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

327-2135-00L Advanced Analytical TEM W Dr 2 credits 3G to be announced

Autumn Semester 2021 Page 1553 of 2152
The course focuses on the fundamental understanding and hands-on knowledge of analytical Transmission Electron Microscopy (ATEM) techniques: electron dispersive X-ray analysis (EDX), energy filtered TEM and electron energy loss spectroscopy (EELS). The lectures will be followed by demonstrations and acquisition sessions TEM instruments. The lectures on statistical treatment of raw data sets and on statistical treatment of raw data sets and on statistical treatment of raw data sets.

Abstract

Objective

- Setting-up the optimal operation conditions for reliable EDX analysis and quantification.
- Setting-up the optimal operation conditions for the reliable EFTEM analyses.
- Setting-up the optimal operation conditions for the reliable EELS analyses.
- EDX data acquisition, on-line analysis and quantification.
- EFTEM data acquisition and analysis.
- EELS acquisition analyses.

Content

1. Fundamentals of analytical TEM.
4. EELS.
5. EFTEM.
7. EDX. Quantification and data evaluation.
8. Demonstrations on EDX, EELS, and EFTEM data acquisitions.
9. Practical sessions for students with provided specimens. Practical sessions for students with their own specimens.
10. Questions and such: open discussion.
11. Student presentations.

Literature


Prerequisites / notice

No mandatory prerequisites. Prior attendance to EM Basic lectures (327-0703-00L, 227-0390-00L) and to the Microscopy Training TEM I - Introduction to TEM course (327-2126-00L) is recommended.

327-2136-00L Chemical Analysis and Spectroscopy for Energy Applications

W Dr 2 credits 2G A. Borgschulte

Abstract

Objective

Applications

Objective

Abstract

Objective

Content

- SYSTEMATICALLY CHARACTERISE THE MICROSTRUCTURE AND PHASES OF A GIVEN MATERIAL WITH X-RAYS AND ELECTRONS
- SELECT THE RIGHT TOOL (SOURCE, INSTRUMENT, MEASUREMENT STRATEGY) AND DESIGN A WORKFLOW FOR SOLVING A MICROSTRUCTURE OR PHASE ANALYSIS PROBLEM
- DESCRIBE POSSIBILITIES AND LIMITATIONS OF A GIVEN CHARACTERISATION METHOD
- COMPREHENSIVELY STORE EXPERIMENTALLY COLLECTED DATA IN A REPOSITORY FOLLOWING MODERN DATA MANAGEMENT RULES SUCH THAT DATA CAN BE EVALUATED BY STUDENTS NOT INVOLVED IN THE EXPERIMENT
- QUALITATIVELY AND QUANTITATIVELY EVALUATE AND PRESENT EXPERIMENTAL DATA AND RESULTS COLLECTED BY OTHERS

Content

The main objective of this hands-on practical course is to give students a comprehensive insight into the most important aspects of microstructure characterization using electron and X-ray scattering. The focus is on the complementarity and exclusivity of the two techniques. We will introduce the most important material characterization tasks, present the relevant physical and crystallographic fundamentals, and discuss how the tasks can be solved with electron and X-ray scattering. We will discuss intrinsic and extrinsic advantages and limitations of the methods and explain essential instrumentation requirements specific to each setup. Another essential facet of the course is the link to everyday D-MATL project problems presented by the lecturers or researchers from D-MATL. The lecture is accompanied by hands-on experiments on samples of D-MATL projects using state-of-the-art instruments.

Literature

Crystallography, X-ray diffraction and electron microscopy on the BSc level. All enrolled students are initially placed on the "waiting list" until the registration deadline. In the case of more than 12 applicants, students will be selected by the lecturers before the start of the lecture according to the priority criteria: master students before doctoral students, Material Science students before students of other departments.

**Prerequisites / notice**
- Crystallography, X-ray diffraction and electron microscopy on the BSc level.
- All enrolled students are initially placed on the "waiting list" until the registration deadline.
- In the case of more than 12 applicants, students will be selected by the lecturers before the start of the lecture according to the priority criteria.

**Taught competencies**
- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Decision-making
  - Problem-solving
- **Domain B - Method-specific Competencies**
- **Domain D - Personal Competencies**
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics

**327-2140-00L Focused Ion Beam and Applications**

- **Objective**
  - Overview of FIB theory, instrumentation.
  - FIB hardware operation and applications.
  - Set-up, align and operate a FIB-SEM successfully and safely.
  - Accomplish operational tasks (milling and deposition) and optimize microscope parameters.
  - Perform cross-sections: preparation and analysis.
  - Understanding of workflow for sample preparation (TEM lamella, APT needles, XCT pillars...) using FIB-SEM.
  - Applying FIB-SEM for materials characterization.
- **Content**
  - This course provides FIB techniques to students with previous SEM experience. At the end of the course, students will be able to set-up a FIB-SEM session and characterize cross-sections. Students will also understand how to prepare TEM & APT samples and design a FIB experiment to solve research problems.
  - Introduction to FIB theory and instrumentation.
  - Discussion of FIB operation and applications.
  - Lecture and demonstration on FIB automation.
  - Practicals on FIB-SEM set-up and alignment.
  - Practicals on cross-section and site-specific sample characterization.
  - Practicals on sample preparation (TEM lamella/APT needles).

**Lecture notes**
Lecture notes will be distributed.

**Literature**

**Prerequisites / notice**
- The students should fulfill one or more of these prerequisites:
  - Prior attendance to the ScopeM Microscopy Training SEM I: Introduction to SEM (327-2125-00L)
  - Prior SEM experience.

**327-2143-00L Computational Multi-Scale Modeling of Solids**

- **Objective**
  - By the end of the course, the student must be able to:
    - Apply an appropriate numerical method for multiphysics simulations to a complex physics problem.
    - Choose suitable methods and tools for (a) the development of, (b) the modelling and simulation of, (c) the analysis of and (d) the choice of solution for an engineering problem in the mechanical engineering domain (product design, manufacturing process and system production).
    - Model the defined problem based on the geometric, kinematic / dynamic, material assumptions while choosing suitable numerical and analytical tools followed by the experimental validation.
    - Apply, adapt and synthesize learned engineering skills to create novel solutions.
    - Derive a finite element formulation from the differential equations in strong form.
    - Explain and apply the concepts of mass, energy, and momentum balance.
    - Explain and apply the concepts of heat and mass transfer.
    - Apply the finite element method to realize a complete study of a real problem.
  - Multi-scale modelling of hard-material systems:
    - Review of material transport, diffusion and viscous flow theory.
    - Multi-scale physics of plasticity in metals ‘from atoms to dislocation line defects to the continuum’.
    - Introduction to the physics and numerics of point particle simulation ‘molecular dynamics and discrete element methods.’
    - Coarse graining strategies and uncertainty quantification.
    - Continuum models of transport and plasticity using the finite element method.

**Content**
- Computational and simulation frameworks:
  - Parallel computing computing materials science and visualization.
  - Multi-scale modelling of hard-material systems:
    - Review of material transport, diffusion and viscous flow theory.
    - Multi-scale physics of plasticity in metals ‘from atoms to dislocation line defects to the continuum’.
    - Introduction to the physics and numerics of point particle simulation ‘molecular dynamics and discrete element methods.’
    - Coarse graining strategies and uncertainty quantification.
    - Continuum models of transport and plasticity using the finite element method.

**101-0121-00L Fatigue and Fracture in Materials and Structures**

- **Objective**
  - In this course, the students will learn:
    - Linear elastic and elastic-plastic fracture mechanics.
    - Modern computer-based techniques (using ABAQUS Finite Element Package) to simulate cracks in both bulk materials and bonded joints/interfaces.
    - Laboratory fatigue and fracture tests on details with cracks.

- **Abstract**
  - The fundamentals in fatigue and fracture mechanics, which are used in different engineering disciplines (e.g., for mechanical, aerospace, civil and material engineers) will be discussed. The focus will be on fundamental theories (based on fracture mechanics) that model fatigue damage and crack propagation.
The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered in this course are:

I) Fatigue of materials:
- Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
- Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner's damage rule.
- Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

II) Fracture mechanics:
- Elastic fracture mechanics (LEFM): limits of LEFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
- Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
- Fatigue crack growth (FCG): FCG models, Paris' law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

III) Introduction to cohesive zone models (CZMs):
- Advantages and disadvantages of CZMs compared to fracture mechanics.
- Different bond-slip models for the bonded joints/interfaces.

IV) Computer laboratory to simulate cracks and debonding problems:
- Finite Element (FE) modeling of complex details with cracks.
- FE simulations of debonding problems using CZMs.
- Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

V) Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

VI) Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and "Laboratory Competition". The students will:
- Visit different small-scale and large-scale fatigue testing equipment.
- Get to know different ongoing fatigue- and fracture-related projects.
- Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
- Compare the experimental results with their own calculations (from the fracture theories).
- "Laboratory Competition" at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded by a prize.

Lecture notes
Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.

Content
The course on Advances in Building Materials provides an introductive overview of the needs and future of materials science in the building sector. Focus topics concern sustainability, durability, thermal insulation, coatings, sealants, adhesives, flame retardancy and the future perspective and developments of concrete and wood with regard to smart material development and ecological concerns.

In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges. The following topics are covered:
1. Material selection
2. Materials and sustainability 1
3. Materials and sustainability 2
4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Prerequisites / notice
Note 1: A basic knowledge on mechanics of structures and structural analysis (i.e., stress-strain analysis and calculations of internal deformations, strains and stresses within structures) is recommended and will be helpful in the course.

Note 2: Laboratory demonstrations and fatigue/fracture tests at the Structural Engineering Research Laboratory of Empa in Dübendorf. This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

101-0617-01L Advances in Building Materials W 4 credits 2G R. J. Flatt, I. Burgert
Objective
In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

Content
The course starts with a discussion on the importance of fatigue and fracture in different engineering disciplines such as mechanical, aerospace, civil and material engineering domains. The preliminary topics that are covered:

1. Fatigue of materials:
   - Mechanisms of fatigue crack initiation in (ductile and brittle) metals.
   - Crack initiation under uni-axial high-cycle fatigue (HCF) loadings: Wöhler (S-N) curves, constant life diagram approach (mean-stress effects), rainflow analysis and Miner's damage rule.
   - Crack initiation under multi-axial HCF loadings: multi-axial fatigue mechanisms, critical plane approach (critical distance theory), equivalent stress approach, proportional and non-proportional loading.

2. Fracture mechanics:
   - Elastic fracture mechanics (LEFM): limits of LEFM, stress intensity factors, crack opening displacement, mixed-mode fracture, etc.
   - Elastic-plastic fracture mechanics: Irwin and Dugdale models, plastic zone shapes, crack-tip opening displacement and J-integral.
   - Fatigue crack growth (FCG): FCG models, Paris' law, cyclic plastic zones, crack closure effects. This also includes FE modeling of the FCG and laboratory tests (at Empa).

3. Introduction to cohesive zone models (CZMs):
   - Advantages and disadvantages of CZMs compared to fracture mechanics.
   - Different bond-slip models for the bonded joints/interfaces.

4. Computer laboratory to simulate cracks and debonding problems:
   - Finite Element (FE) modeling of complex details with cracks.
   - FE simulations of debonding problems using CZMs.
   - Computer laboratory: FE training and exercises using (the student edition of) the ABAQUS FE Package.

5. Introduction to fatigue and fracture design in civil structures. Different methods for fatigue strengthening will be discussed.

6. Visits to the Empa (Swiss Federal Laboratories for Materials Science and Technology) in Dübendorf, and "Laboratory Competition". The students will:
   - Visit different small-scale and large-scale fatigue testing equipment.
   - Get to know different ongoing fatigue- and fracture-related projects.
   - Witness and help to conduct a fatigue test on a steel plate with a pre-crack and a fracture test on an adhesively-bonded joint.
   - Compare the experimental results with their own calculations (from the fracture theories).
   - "Laboratory Competition" at Empa: the students with the closest predictions will win the “Empa Laboratory Competition” and will be awarded by a prize.

Lecture notes
Lectures are based on the lecture slides and the handouts, which will be given to the students during the semester.

Literature

Prerequisites / notice
Note 1: A basic knowledge on mechanics of structures and structural analysis (i.e., stress-strain analysis and calculations of internal deformations, strains and stresses within structures) is recommended and will be helpful in the course.

Note 2: Laboratory demonstrations and fatigue/fracture tests at the Structural Engineering Research Laboratory of Empa in Dübendorf. This includes laboratory tours and showcasing the Empa large-scale 7-MN fatigue testing machine for bridge cables, different fatigue and fracture testing equipment for structural components, etc.

101-0617-01L Advances in Building Materials W 4 credits 2G R. J. Flatt, I. Burgert
Objective
In this course, the students will gain a broad overview of the use of materials in the building sector, with a particular focus on concrete and wood. Current limitations and in particular sustainability related challenges will be detailed with the objective of laying the grounds to discuss future developments anticipated in this field.

Content
This course for civil engineers lays the grounds in the specialization Materials and Mechanics and complements the second introductory course of the specialization on Numerical Mechanics of Materials. The course also addresses master students in Materials Science and other study programs interested in deepening their understanding of application-relevant properties of engineering materials and sustainability related challenges. The following topics are covered:
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4. Recyclability
5. Material science of wood durability
6. Material science of concrete durability
7. Foams in construction and thermal insulation
8. Sealants and adhesives in construction
9. Coatings
10. Flame retardants
11. Future of wood – 1
12. Future of wood – 2
13. Future of concrete – 1
14. Future of concrete – 2

Lecture notes
Handouts will be provided for each lecture.

101-0677-00L Concrete Technology W 2 credits 2G F. Constandopoulos, M. Bäuml, G. Martinola, T. Wangler
Objective
Opportunities and limitations of concrete technology, Commodities and leading edge specialties.

Advanced education in concrete technology for civil engineers who are designing, specifying and executing concrete structures.
Based on the lecture 'Werkstoffe' students receive deep concrete technology training. Comprehensive knowledge of the most important properties of conventional concrete and the current areas of research in concrete technology will be presented. The course covers various topics, including:

- concrete components
- concrete properties
- concrete mix design
- production, transport, casting
- demoulding, curing and additional protective measures
- durability
- standards
- chemical admixtures
- alternative binders
- specialty concretes such as
  - self compacting concrete
  - fiber reinforced concrete
  - fast setting concrete
  - fair faced concrete
  - recycled concrete
- new research in digital fabrication with concrete

Lecture notes
Slides provided for download.

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

Abstract
Focus is on laminated fibre reinforced polymer composites. The courses treats aspects related to micromechanics, elastic behavior of unidirectional and multidirectional laminates, failure and damage analysis, design and analysis of composite structures.

Objective
To introduce the underlying concept of composite materials and give a thorough understanding of the mechanical response of materials and structures made from fibre reinforced polymer composites, including elastic behaviour, fracture and damage analysis as well as structural design aspects. The ultimate goal is to provide the necessary skills to address the design and analysis of modern lightweight composite structures.

Content
The course is addressing following topics:
- Introduction
- Elastic anisotropy
- Micromechanics aspects
- Classical Laminate Theory (CLT)
- Failure hypotheses and damage analysis
- Analysis and design of composite structures
- Variable stiffness structures

Literature
The lecture material is covered by the script and further literature is referenced in there.

Lecture notes
Script, handouts, exercises and additional material are available in PDF-format on the CMASLab webpage resp on moodle.

https://moodle-app2.let.ethz.ch/course/view.php?id=2610

Metal Additive Manufacturing - Mechanical Integrity and Numerical Analysis

Abstract
An introduction to Metal Additive Manufacturing (MAM) (e.g. different techniques, the metallurgy of common alloy-systems, existing challenges) will be given. The focus of the lecture will be on the employment of different simulation approaches to address MAM challenges and to enable exploiting the full advantage of MAM for the manufacture of structures with desired property and functionality.

Objective
The main objectives of this lecture are:
- Acknowledging the possibilities and challenges for MAM (with a particular focus on mechanical integrity aspects),
- Understanding the importance of material science and metallurgical considerations in MAM,
- Appreciating the importance of thermal, fluid, mechanical and microstructural simulations for efficient use of MAM technology,
- Using different commercial analysis tools (COMSOL, ANSYS, ABAQUS) for simulation of the MAM process.


Objective
Familiarize students with basic science and engineering principles governing the nano domain.

151-0605-00L Nanosystems W 4 credits 4G A. Stemmer
Abstract
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. Intermolecular forces, their macroscopic manifestations, and ways to control such interactions. Self-assembly and directed assembly of 2D and 3D structures. Special emphasis on the emerging field of molecular electronic devices.

Content
- Introduction to MAM (concept, application examples, pros & cons),
- Powder-bed and powder-blown metal additive manufacturing,
- Thermo-fluid analysis of additive manufacturing,
- Continuum-based thermal modeling and experimental validation techniques,
- Residual stresses and distortion simulation and verification methods,
- Microstructural simulation (basics, analytical, kinetic Monte Carlo, cellular automata, phase-field),
- Mechanical property prediction for MAM,
- Microstructure and mechanical response of MAM material (steels, Ti6Al4V, Inconel, AI alloys),
- Design for additive manufacturing
- Artificial intelligence for AM

Exercise sessions use COMSOL, ANSYS, ABAQUS packages for analysis of MAM process. Detailed video instructions will be provided to enable students to set up their own simulations. COMSOL, ANSYS and ABAQUS agreed to support the course by providing licenses for the course attendees and therefore the students can install the packages on their own systems.

Lecture notes
Handouts of the presented slides.

Literature
No textbook is available for the course (unfortunately), since it is a dynamic and relatively new topic. In addition to the material presented in the course slides, suggestions/recommendations for additional literature/publications will be given (for each individual topic).

Prerequisites / notice
A basic knowledge of mechanical analysis, metallurgy, thermodynamics is recommended.

151-0550-00L Adaptive Materials for Structural Applications W 4 credits 3G A. Bergamini
Abstract
Adaptive materials offer appealing ways to extend the design space of structures by introducing time-variable properties into them. In this course, the physical working principles of selected adaptive materials are analyzed and simple models for describing their behavior are presented. Some applications are illustrated, also with laboratory experiments where possible.

Objective
The study of adaptive materials covers topics that range from chemistry to theoretical mechanics. The aim of this course is to convey knowledge about adaptive materials, their properties and the physical mechanisms that govern their function, so as to develop the skills to deal with this interdisciplinary subject.

Content
This course will provide the students with an insight into the properties and physical phenomena which lead to the features of adaptive materials. Starting from chemomechanical (skeletal muscles), the physical behavior of a wide range of adaptive materials, thermo- and photo-mechanical, electro-mechanical, magneto-mechanical and meta-materials will be thoroughly discussed and analyzed. Up-to-date results on their performance and their implementation in mechanical structures will be detailed and studied in laboratory sessions.

Basic concepts: Power conjugated variables, dissipative effects, geometry- and materials-based energy conversion


Thermo-mechanical coupling: Shape memory alloys / polymers

Electromechanical coupling(1): DEA, EBL, electrorheological fluids

Shape control / morphing: Use, requirements, challenges

Morphing applications of variable stiffness structures: Lab work

Electromechanical coupling (2): Piezoelectric, electrostrictive effect

Vibration Reduction: Measurement, passive, semi-active (active) damping methods

Vibration reduction applications of piezoelectric materials: Lab work

Metamaterials: Definition of metamaterials - electromagnetic, acoustical and other metamaterials

Energy harvesting and sensing: Energy harvesting with EAP and piezoelectric materials, transducers as sensors: Piezo, resistive,....
The course addresses basic science and engineering principles ruling the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.
Self-assembly and directed assembly of 2D and 3D structures.


Prerequisites / notice

Lectures and Mini-Review presentations: Thursday 10-13

Homework: Mini-Review (compulsory continuous performance assessment)

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented both orally and as a written paper.

227-0617-00L Solar Cells W 4 credits 3G A. N. Tiwari, R. Carron, Y. Romanyuk

Abstract
Physics, technology, characteristics and applications of photovoltaic solar cells.

Objective
Introduction to solar radiation, physics, technology, characteristics and applications of photovoltaic solar cells and systems.

Content
Solar radiation characteristics, physical mechanisms for the light to electrical power conversion, properties of semiconductors for solar cells, processing and properties of conventional Si and GaAs based solar cells, technology and physics of thin film solar cells based on compound semiconductors, other solar cells including organic and dye sensitized cells, problems and new developments for power generation in space, interconnection of cells and solar module design, measurement techniques, system design of photovoltaic plants, system components such as inverters and controllers, engineering procedures with software demontration, integration in buildings and other specific examples.

Prerequisites / notice
Lecture reprints (in english).
Prerequisites: Basic knowledge of semiconductor properties.

227-0619-00L Charge Transport in Energy Conversion and Storage Devices W 6 credits 2V+2U C. Battaglia, A. Senocate

Abstract
The students will be introduced to the fundamental concepts of charge transport in solar cells, batteries, and electrolyzers. Emphasizing analogies between semiconductor physics and electrochemistry, this course is designed to provide a unified modern perspective of energy conversion and storage concepts for students in electrical engineering, materials science, physics, and chemistry.

Objective
By the end of this course, the students will (1) understand the fundamentals of electronic and ionic charge transport, (2) understand the operational principles of solar cells, batteries, and electrolyzers, and (3) understand fundamental limits for each device type. In addition, the students will learn how to simulate these devices during guided exercise sessions and develop an intuitive understanding on how to interpret the most important device characteristics.

Literature
- R. Huggins, Advanced Batteries, DOI:10.1007/978-0-387-76474-5

Prerequisites / notice
Be motivated to change the world to renewable energies! Elements of calculus will be reviewed at the beginning of the course, but we leave the hard work of solving coupled differential charge transport equations to the computer and focus on developing a strong intuition. Prior knowledge in semiconductor physics or electrochemistry is an advantage, but not a prerequisite. Students are required to bring a windows-compatible computer with a common data analysis software to the exercises. Apps for simulating devices under different operating conditions will be made available to the students. A visit to a solar cell or battery lab will be organized during the semester if the epidemiological situation permits.

376-1103-00L Frontiers in Nanotechnology W 4 credits 4V V. Vogel, further lecturers

Abstract
Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

Objective
Building upon advanced technologies to create, visualize, analyze and manipulate nano-structures, as well as to probe their nano-chemistry, nano-mechanics and other properties within mammade and living systems, many exciting discoveries are currently made. They change the way we do science and result in so many new technologies.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.
Content
Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

Lecture notes
All the enrolled students will get access to a password protected website where they can find pdf files of the lecture notes, and typically 1-2 journal articles per lecture that cover selected topics.

376-1714-00L Biocompatible Materials W 4 credits 3V K. Manus, M. Rottmar, M. Zenobi-Wong

Abstract
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

Objective
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Content
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Lecture notes
Handouts are deposited online (moodle).

Literature

(available online via ETH library)

402-0317-00L Semiconductor Materials: Fundamentals and Fabrication W 6 credits 2V+1U S. Schön, W. Wegscheider

Abstract
This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

Objective
Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing

Content
1. Fundamentals of Solid State Physics
   1.1 Semiconductor materials
   1.2 Band structures
   1.3 Carrier statistics in intrinsic and doped semiconductors
   1.4 p-n junctions
   1.5 Low-dimensional structures
2. Bulk Material growth of Semiconductors
   2.1 Czochalski method
   2.2 Floating zone method
   2.3 High pressure synthesis
3. Semiconductor Epitaxy
   3.1 Fundamentals of Epitaxy
   3.2 Molecular Beam Epitaxy (MBE)
   3.3 Metal-Organic Chemical Vapor Deposition (MOCVD)
   3.4 Liquid Phase Epitaxy (LPE)
   4. In situ characterization
   4.1 Pressure and temperature
   4.2 Reflectometry
   4.3 Ellipsometry and RAS
   4.4 LEED, AES, XPS
   4.5 STM, AFM
   5. The invention of the transistor - Christmas lecture

Lecture notes
https://moodle-app2.let.ethz.ch/course/view.php?id=15519

Prerequisites / notice
The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture.

402-0535-00L Introduction to Magnetism W 6 credits 3G A. Vindigni

Abstract
Atomic paramagnetism and diamagnetism, itinerant and local-moment interatomic coupling, magnetic order at finite temperature, spin precession, approach to equilibrium through thermal and quantum dynamics, dipolar interaction in solids.

Objective
- Apply concepts of quantum-mechanics to estimate the strength of atomic magnetic moments and their interactions
- Identify the mechanisms from which exchange interaction originates in solids (itinerant and local-moment magnetism)
- Evaluate the consequences of the interplay between competing interactions and thermal energy
- Apply general concepts of statistical physics to determine the origin of bistability in realistic magnets
- Discriminate the dynamic responses of a magnet to different external stimuli
The lecture "Introduction to Magnetism" is a regular course of the Physics MSc program and aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what "being magnetic" means is essential to address this question properly. Theoretical concepts will be applied to few selected nano-sized magnets, which will serve as clean reference systems.

At the end of this course students should have acquired the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Preliminary contents for the HS21:
- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field).
- Spin resonance and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)
- Magnetic order at finite temperatures (Ising and Heisenberg models, low-dimensional magnetism)
- Dipolar interaction in solids (shape anisotropy, dipolar frustration, origin of magnetic domain)

**Lecture notes / notice**
Learning material will be made available through a dedicated RStudioServer and through Moodle.

**Literature recommendations and references** are included in the lecture notes.

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

**Objective**

- The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

**Content**

1. Introduction and overview
2. Semiconductor crystals, fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k.p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

**Lecture notes / notice**

In addition to the lecture notes, the following supplementary books can be recommended:


**Prerequisites / notice**

- The course is taught in English.
- The course is suitable for all physics students beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitioned students in the third year may be able to follow. The lecture can be chosen as part of the PhD-program.

**Taught competencies**

- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: not assessed

- Domain C - Social Competencies
  - Communication: not assessed
  - Self-presentation and Social Influence: assessed

- Domain D - Personal Competencies
  - Sensitivity to Diversity: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: assessed
  - Self-direction and Self-management: not assessed

**402-0809-00L Introduction to Computational Physics**

**Abstract**

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

**Objective**

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes / notice**

Lecture notes and slides are available online and will be distributed if desired.

**Literature**

- Literature recommendations and references are included in the lecture notes.

**Prerequisites / notice**

Lecture and exercise lessons in English, exams in German or in English

**529-0659-00L Electrochemistry: Fundamentals, Cells & Applications**

**Abstract**

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

**Objective**

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

**Content**

Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes / notice**

Lecture notes and slides are available online and will be distributed if desired.

**Literature**

- Literature recommendations and references are included in the lecture notes.

**Prerequisites / notice**

Lecture and exercise lessons in English, exams in German or in English
Introduction to electrochemistry from a physical chemistry point of view, focusing on thermodynamics and kinetics of electrochemical reactions, and engineering of electrochemical cells. The topics are of generic nature yet also discussed in the context of specific applications in industrial electrochemistry, energy storage and conversion, electroanalytical techniques, sensors and corrosion.

The course establishes the fundamentals to understand and describe electrochemical reactions. The students are familiarized with key concepts and approaches in electrochemistry and selected aspects of materials science and engineering and how they are put to use in selected applications.

- **Abstract**
  Introduction: important quantities & units, terminology;
  - Chapter I - redox reactions, Faraday’s laws;
  - Chapter II - Equilibrium electrochemistry:
    cells, galvanic and electrolytic cells, thermodynamic state functions, theoretical cell voltage, half-cell / electrode potential, hydrogen electrode, the electrochemical series, Nernst equation;
  - Chapter III - Electrodes & interfaces:
    electrochemical potential, phase potentials, work function, Fermi level, the electrified interface, the electrochemical double layer, reference electrodes and laboratory cells;
  - Chapter IV - Electrolytes:
    conductivity, aqueous electrolytes, transference effects, liquid junctions, polymer electrolytes, ion-exchange membranes, Donnan exclusion, solid state ion conductors;
  - Chapter V - Dynamic electrochemistry:
    overpotentials, description of charge-transfer reaction, Butler-Volmer and Tafel equation, exchange current density, mass transport limitations;
  - Chapter VI - Industrial electrochemistry:
    electrochemical engineering, process and reactor types, current density distribution, porous electrodes, chlor-alkali and HCl electrolysis, oxygen depolarized cathode;
  - Chapter VII - Energy storage & conversion:
    important primary and secondary battery chemistries, fuel cells, polymer electrolyte fuel cells, low temperature H2 and O2 electrochemistry, electrocatalysis, triple-phase boundary, solid oxide fuel cell, conversion efficiency;
  - Chapter VIII - Electroanalytical methods & sensors:
    potentiometry, cyclic and stripping voltammetry, rotating disc electrode studies, electrochemical sensors;
  - Chapter IX - Corrosion:
    Pourbaix diagram, corrosion potential, passivation, corrosion protection; Historical notes

- **Lecture notes**
  lecture notes, exercise & solutions (PDF files) via download website

- **Literature**

- **Prerequisites / notice**
  Students should be familiar with the fundamentals of physical chemistry.

- **Taught competencies**
  Domain A - Subject-specific Competencies
  Concepts and Theories
  assessed

- **Number**
  ECTS
  Hours
  Lecturers

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>327-1210-00L</td>
<td>Project I</td>
<td>O</td>
<td>12</td>
<td>23A</td>
<td>Professors</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Independent scientific practice of 8 weeks which is completed with a written report.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Projects, with themes from the chosen scientific fields of interest, are intended to familiarise candidates with scientific procedures and operational methodologies through supervised participation in current research work.</td>
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<td>327-1211-00L</td>
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<td>Independent scientific practice of 8 weeks which is completed with a written report.</td>
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- **Master’s Thesis**

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<th>Hours</th>
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<td>Master’s Thesis</td>
<td>O</td>
<td>30</td>
<td>64D</td>
<td>Professors</td>
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</tbody>
</table>

- **Abstract**
  Independent scientific work of current topics in the field of materials science. Duration 6 months. The work is documented in a written form.
Objective

Master thesis is a six month fulltime project and will encourage the students to work independently and in a structured and scientific way. It is guided by a professor of the Department of Materials.

GESS Science in Perspective

see GESS Science in Perspective: Language Courses ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MATL.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

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<thead>
<tr>
<th>Number</th>
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<td>327-0503-AAL</td>
<td>Ceramics I</td>
<td>E-</td>
<td>3</td>
<td>R</td>
<td>M. Niederberger, A. Demirörs, T. Graule</td>
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<td>327-0502-AAL</td>
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<td>3</td>
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<td>M. Kröger</td>
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<td>327-0606-AAL</td>
<td>Polymers II</td>
<td>E-</td>
<td>3</td>
<td>R</td>
<td>T. A. Tervoort, T.-B. Schweizer</td>
</tr>
</tbody>
</table>

Abstract

Introduction to ceramic processing

Objective

The aim is the understanding of the basic principles of ceramic processing.

Content

Basic chemical processes for powder production.
Liquid-phase synthesis methods.
Sol-Gel processes.
Classical crystallization theory.
Gas phase reactions.
Basics of the colloidal chemistry for suspension preparation and control.
Characterization techniques for powders and colloids.
Shaping techniques for bulk components and thin films.
Sintering processes and microstructural control.

Literature

Books and references will be provided on the lecture notes.

Prerequisites / notice

Computer experiments will use the simple MATLAB programming language and will be made available, if necessary or useful.

http://www.polyphys.mat.ethz.ch/education/courses/polymers-I

Content
1. Crystallization of semi-crystalline polymers
2. Glass transition of amorphous polymers
3. Mechanical properties of solid polymers
4. Examples of polymer processing
5. Laboratory exercises

Lecture notes
In consultation with the teachers (Tervoort and Schweizer).

Literature
W. Kaiser, Kunststoffchemie für Ingenieure (Hanser, München, 2005)

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**327-0501-AAL  Metals I**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
Repetition and advancement of dislocation theory. Mechanical properties of metals: hardening mechanisms, high temperature plasticity, alloying effects. Case studies in alloying to illustrate the mechanisms.

**Objective**
Repetition and advancement of dislocation theory. Mechanical properties of metals: hardening mechanisms, high temperature plasticity, alloying effects. Case studies in alloying to illustrate the mechanisms.

**Content**
Dislocation theory:
- Properties of dislocations, motion and kinetics of dislocations, dislocation-dislocation and dislocation-boundary interactions, consequences of partial dislocations, sessile dislocations
- Hardening theory:
  a. solid solution hardening: case studies in copper-nickel and iron-carbon alloys
  b. particle hardening: case studies on aluminium-copper alloys
- High temperature plasticity:
  thermally activated glide
  power-law creep
diffusional creep: Coble, Nabarro-Herring
deflection mechanism maps
  Case studies in turbine blades
  superplasticity
  alloying effects

**Lecture notes**
https://www.met.mat.ethz.ch/education/lect_scripts

**Literature**
Gottstein, Physikalische Grundlagen der Materialkunde, Springer Verlag
Haasen, Physikalische Metallkunde, Springer Verlag
Rüssler/Harders/Bäker, Mechanisches Verhalten der Werkstoffe, Teubner Verlag
Porter/Easterling, Transformations in Metals and Alloys, Chapman & Hall
Hull/Bacon, Introduction to Dislocations, Butterworth & Heinemann
Courtney, Mechanical Behaviour of Materials, McGraw-Hill

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**327-0612-AAL  Metals II**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
Introduction to materials selection. Basic knowledge of major metallic materials: aluminium, magnesium, titanium, copper, iron and steel. Selected topics in high temperature materials: nickel and iron-base superalloys, intermetallics and refractory metals.

**Objective**
Introduction to materials selection. Basic knowledge of major metallic materials: aluminium, magnesium, titanium, copper, iron and steel. Selected topics in high temperature materials: nickel and iron-base superalloys, intermetallics and refractory metals.

**Content**
This course is divided into five parts:

A. Materials selection
- Principles of materials properties maps
- Introduction to the 'Materials selector' software package
- Case studies

B. Light metals and alloys
- Aluminium, magnesium, titanium
- Properties and hardening mechanisms
- Case studies in technological applications

C. Copper and its alloys

D. Iron and steel
- The seven pros for steel
- Fine grained steels, heat resistant steels
- Steel and corrosion phenomena
- Selection and application

E. High temperature alloys
- Superalloys: iron, nickel, cobalt
- Intermetallics: properties and application

**Lecture notes**
http://www.met.mat.ethz.ch/education/lect_scripts

**Literature**
Gottstein, Physikalische Grundlagen der Materialkunde, Springer Verlag
Ashby/Jones, Engineering Materials 1 & 2, Pergamon Press
Ashby, Materials Selection in Mechanical Design, Pergamon Press
Porter/Easterling, Transformations in Metals and Alloys, Chapman & Hall
Bürgel, Handbuch Hochtemperatur-Werkstofftechnik, Vieweg Verlag

**Prerequisites / notice**
Prerequisites: Metals I

---

**327-0610-AAL  Advanced Composites**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students,
Abstract
Introduction of basic concepts for composites with polymer- metal- and ceramic matrix composites; production and properties of composites reinforced with particles, whiskers, short and long fibres; selection criteria, case histories of applications, recycling, future perspectives, and basic concepts for adaptive and functional composites

Objective
Gain an insight into the diversity of opportunities to change the properties of composites, learn about the most important applications and processing techniques

Content
1. Introduction
   1.1 What are advanced composites?
   1.2 What are materials by combination?
   1.3 Are composites an idea of today?
   1.4 Delphi foresight
   1.5 Why composites?
   1.6 References for chapter 1

2. Basic modules
   2.1 Particles
   2.2 Short fibres including whiskers
   2.3 Long fibres
   2.4 Matrix materials
   2.4.1 Polymers
   2.4.2 Metals
   2.4.3 Ceramics and glasses
   2.5 References for chapter 2

3. PMC: Polymer Matrix Composites
   3.1 Historical background
   3.2 Types of PMC-laminates
   3.3 Production, processing and machining operation
   3.4 Mechanics of reinforcement, microstructure, interfaces
   3.5 Failure criteria
   3.6 Fatigue behaviour of a multiply composite
   3.7 Adaptive materials systems
   3.8 References for chapter 3

4. MMC: Metal matrix composites
   4.1 Introduction: Definitions, selection criteria und *design*
   4.2 Types von MMCs - examples und typical properties
   4.3 Mechanical and physical properties of MMCs - basics of design, influencing variables and damage mechanisms
   4.4 Production processes
   4.5 Micro structure / interfaces
   4.6 machining operations for MMC
   4.7 Applications
   4.8 References for chapter 4

5. CMC: Ceramic Matrix Composites
   5.1 Introduction and historical background
   5.2 Modes of reinforcement
   5.3 Production processes
   5.4 Mechanisms of reinforcement
   5.5 Micro structure / interfaces
   5.6 Properties
   5.7 Applications
   5.8 Materials testing and quality assurance
   5.9 References for chapter 5

Lecture notes
The script will be delivered at the begin of the semester

Literature
The script is including a comprehensive list of references

Prerequisites / notice
Before each class, students will get a handout. Students will get the power point presentation of each class by e-mail.

The exercises take place in small groups. It is their goal to deepen knowledge gained in the classes

written end of semester examination

Materials Science Master - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Mathematics (General Courses)

#### Generally Accessible Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-5000-00L</td>
<td>Zurich Colloquium in Mathematics</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>R. Abgrall, M. Iacobelli, A. Bandeira, A. Iozzi, S. Mishra, R. Pandharipande, University lecturers</td>
</tr>
<tr>
<td>401-5960-00L</td>
<td>Colloquium on Mathematics, Computer Science, and Education</td>
<td>E-</td>
<td>0</td>
<td></td>
<td>N. Hungerbühler, M. Akveld, D. Grawehr Morath, J. Hromkovic, P. Spindler</td>
</tr>
</tbody>
</table>

**Abstract**

Didactics colloquium

#### Actuary SAA Education at ETH Zurich

*Further pieces of information are available at Prof. M. Wüthrich's secretariat, HG F 42.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3925-00L</td>
<td>Non-Life Insurance: Mathematics and Statistics</td>
<td>W</td>
<td>8</td>
<td>4V+1U</td>
<td>M. V. Wüthrich</td>
</tr>
</tbody>
</table>

**Abstract**

The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency.

**Objective**

The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

**Content**

- Collective Risk Modeling
- Individual Claim Size Modeling
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tariffication
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

**Lecture notes**

M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics
http://ssrn.com/abstract=2319328

**Literature**

M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications
http://ssrn.com/abstract=3822407

**Prerequisites / notice**

This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

**Prerequisites:** knowledge of probability theory, statistics and applied stochastic processes.

**Taught competencies**

- Domain A - Subject-specific Competencies: Concepts and Theories - assessed
- Domain A - Subject-specific Competencies: Techniques and Technologies - assessed
- Domain B - Method-specific Competencies: Decision-making - assessed
- Domain B - Method-specific Competencies: Media and Digital Technologies - not assessed
- Domain B - Method-specific Competencies: Problem-solving - assessed
- Domain B - Method-specific Competencies: Project Management - not assessed

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3922-00L</td>
<td>Life Insurance Mathematics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Koller</td>
</tr>
</tbody>
</table>

**Abstract**

The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>401-3929-00L</td>
<td>Financial Risk Management in Social and Pension Insurance</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. Blum</td>
</tr>
</tbody>
</table>

**Abstract**

Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. We study short-term and long-term financial risk and its interplay with other risk factors, and we develop methods for the measurement and management of financial risk and return in an asset/liability context with the goal of assuring sustainable funding.
Understand the basic asset-liability framework: essential principles and properties of social and pension insurance; cash flow matching, duration matching, valuation portfolio and loose coupling; the notion of financial risk; long-term vs. short-term risk; coherent measures of risk.

Understand the conditions for sustainable funding: derivation of required returns; interplay between return levels, contribution levels and other parameters; influence of guaranteed benefits.

Understand the notion of risk-taking capability: capital process as a random walk; measures of long-term risk and relation to capital; short-term solvency vs. long-term stability; effect of embedded options and guarantees; interplay between required return and risk-taking capability.

Be able to study empirical properties of financial assets: the Normal hypothesis and the deviations from it; statistical tools for investigating relevant risk and return properties of financial assets; time aggregation properties; be able to conduct analysis of real data for the most important asset classes.

Understand and be able to carry out portfolio construction: the concept of diversification; limitations to diversification; correlation breakdown; incorporation of constraints; sensitivities and shortcomings of optimized portfolios.

Understand and interpret the asset-liability interplay: the optimized portfolio in the asset-liability framework; short-term risk vs. long-term risk; the influence of constraints; feasible and non-feasible solutions; practical considerations.

Understand and be able to address essential problems in asset / liability management, e.g. optimal risk / return positioning, optimal discount rate, target value for funding ratio or turnaround issues.

Have an overall view: see the big picture of what asset returns can and cannot contribute to social security; be aware of the most relevant outcomes; know the role of the actuary in the financial risk management process.

Risk and return of financial assets cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

Extensive handouts will be provided. Moreover, practical examples and data sets in Excel and R will be made available.

Solid base knowledge of probability and statistics is indispensable. Specialized concepts from financial and insurance mathematics as well as quantitative risk management will be introduced in the lecture as needed, but some prior knowledge in some of these areas would be an advantage.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.

<table>
<thead>
<tr>
<th>401-3928-00L</th>
<th>Reinsurance Analytics</th>
<th>W 4 credits</th>
<th>2V</th>
<th>P. Antal, P. Arbenz</th>
</tr>
</thead>
</table>
| Objective    | This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and models for extreme events such as natural or man-made catastrophes. The lecture covers reinsurance contracts, Experience and Exposure pricing, natural catastrophe modelling, solvency regulation, and insurance linked securities. This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes. Topics covered include:
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds. |
This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

Topics covered include:
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency II.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

The course counts towards the diploma of "Aktuar SAV". The exams ONLY take place during the official ETH examination period.

Good knowledge in probability theory and stochastic processes is assumed. Some knowledge in financial mathematics is useful.
Lecture notes will be sold at the beginning of the course. Additional (background) references are given there.
Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitstheorie").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

363-0565-00L Principles of Macroeconomics W 3 credits 2V J.-E. Sturm

Abstract
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

Content
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer. Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes
The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

Literature
The set-up of the course will closely follow the book of N. Gregory Mankiw and Mark P. Taylor (2020), Economics, Cengage Learning, Fifth Edition. This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain C - Social Competencies</td>
<td>Adaptability and Flexibility</td>
<td>Creative Thinking</td>
<td>Critical Thinking</td>
<td>Integrity and Work Ethics</td>
<td>Self-awareness and Self-reflection</td>
<td>Self-direction and Self-management</td>
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</tr>
</tbody>
</table>

Mathematics (General Courses) - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture | P | practical/laboratory course |
| G | lecture with exercise | A | independent project |
| U | exercise | D | diploma thesis |
| S | seminar | R | revision course / private study |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
# Mathematics Bachelor

## Bachelor Studies (Programme Regulations 2021)

### First Year Compulsory Courses

#### First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10 credits</td>
<td>6V+3U</td>
<td>M. Einsiedler</td>
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<td>Abstract</td>
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<tr>
<td></td>
<td>Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.</td>
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<td>Objective</td>
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<td></td>
<td>The ability to work with the basics of calculus in a mathematically rigorous way.</td>
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<tr>
<td></td>
<td>H. Amann, J. Escher: Analysis I</td>
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<td></td>
<td>J. Appell: Analysis in Beispielen und Gegenbeispielen</td>
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<td></td>
<td>R. Courant: Vorlesungen über Differential- und Integralrechnung</td>
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<td></td>
<td>O. Forster: Analysis I</td>
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<td>H. Heuser: Lehrbuch der Analysis</td>
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<td></td>
<td>K. Königsberger: Analysis 1</td>
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<td>W. Walter: Analysis 1</td>
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<td>V. Zorich: Mathematical Analysis I (englisch)</td>
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<tr>
<td></td>
<td>A. Beutelspacher: &quot;Das ist o.B.d.A. trivial&quot;</td>
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<tr>
<td></td>
<td>H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten</td>
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<tr>
<td>402-1701-00L</td>
<td>Physics I</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>K. Ensslin</td>
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<td>Abstract</td>
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<tr>
<td></td>
<td>This course gives a first introduction to Physics with an emphasis on classical mechanics.</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.</td>
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<tr>
<td>252-0847-00L</td>
<td>Computer Science</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>R. Sasse, F. O. Friedrich Wicker</td>
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<tr>
<td></td>
<td>Abstract</td>
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<tr>
<td></td>
<td>The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.</td>
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<td>Objective</td>
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<td></td>
<td>Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens &quot;behind the scenes&quot; when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.</td>
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<tr>
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<td>Literature</td>
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<tr>
<td></td>
<td>Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010</td>
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<td></td>
<td>Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000</td>
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#### First Year Examination Block 2

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<tr>
<td>401-1151-00L</td>
<td>Linear Algebra I</td>
<td>O</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>R. Pink</td>
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<td>Abstract</td>
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<td>Objective</td>
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<tr>
<td></td>
<td>- Mastering basic concepts of Linear Algebra</td>
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<tr>
<td></td>
<td>- Introduction to mathematical methods</td>
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<td>Content</td>
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</tr>
<tr>
<td></td>
<td>- Basics</td>
<td></td>
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<tr>
<td></td>
<td>- Vectorspaces and linear maps</td>
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<tr>
<td></td>
<td>- Systems of linear equations and matrices</td>
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<td>- Determinants</td>
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<td></td>
<td>- Endomorphisms and eigenvalues</td>
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Bachelors Studies (Programme Regulations 2016)

First Year

Course units of the first year can be found in section Bachelor Studies (Programme Regulations 2021) - First Year Compulsory Courses.

Compulsory Courses

Examination Block I

In Examination Block I either the course unit 402-2883-00L Physics III or the course unit 402-2203-01L Classical Mechanics must be chosen and registered for an examination. (Students may also enrol for the other of the two course units; within the ETH Bachelors programme in mathematics, this other course unit cannot be registered in myStudies for an examination nor can it be recognised for the Bachelor's degree.)

<table>
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<td>401-2303-00L</td>
<td>Complex Analysis</td>
<td>O</td>
<td>6 credits</td>
<td>3V+2U</td>
<td>T. H. Willwacher</td>
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<tr>
<td>Abstract</td>
<td>Complex functions of one variable, Cauchy-Riemann equations, Cauchy theore...</td>
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<td>Objective</td>
<td>Working knowledge of functions of one complex variable, in particular applications of the residue theorem.</td>
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<tr>
<td>Literature</td>
<td>B. Palka: &quot;An introduction to complex function theory.&quot;</td>
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</table>


Th. Gamelin: Complex Analysis. Springer 2001


D. Salamon: "Funktionentheorie". Birkhäuser, 2011. (In German)


K. Jänich: Funktionentheorie. Springer Verlag

R. Remmert: Funktionentheorie I. Springer Verlag

E. Hille: Analytic Function Theory. AMS Chelsea Publications

<table>
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<tr>
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<td>401-2333-00L</td>
<td>Methods of Mathematical Physics I</td>
<td>O</td>
<td>6 credits</td>
<td>3V+2U</td>
<td>G. Felder</td>
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<td>402-2883-00L</td>
<td>Physics III</td>
<td>W</td>
<td>7 credits</td>
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<td>U. Keller</td>
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<tr>
<td>Abstract</td>
<td>Introductory course on quantum and atomic physics including optics and statistical physics. A basic introduction to quantum and atomic physics, including basics of optics and equilibrium statistical physics. The course will focus on the relation of these topics to experimental methods and observations.</td>
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<td>Objective</td>
<td>Einführung in die Quantenphysik: Plancksche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford Streuung, Compton Streuung, Bohrsche Atommodell, de-Broglie Materiewellen.</td>
<td></td>
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<tr>
<td>Content</td>
<td>Optik/Wellenoptik: Linsen, Abbildungssysteme, Brechung und Fermatsches Prinzip, Beugung, Interferenz, Fabry-Perot, Interferometer, Spektrometer.</td>
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<td>Literature</td>
<td>Quantenmechanik: Dualismus Teilchen-Welle, Wellenfunktionen, Operatoren, Schrödinger-Gleichung, Potentialstufe und Potentialkasten, harmonischer Oszillator</td>
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<tr>
<td>Literature</td>
<td>M. Alonso, E. J. Finn</td>
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<tr>
<td></td>
<td>Quantenphysik und Statistische Physik</td>
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<td></td>
<td>R. Oldenburg Verlag, München</td>
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<td>5. Auflage</td>
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<td>ISBN 978-3-486-71340-4</td>
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<tr>
<td>402-2203-01L</td>
<td>Classical Mechanics</td>
<td>W</td>
<td>7 credits</td>
<td>4V+2U</td>
<td>R. Renner</td>
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<tr>
<td>Abstract</td>
<td>A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, spinning top, relativistic space-time structure, particles in an electromagnetic field, Hamiltonian mechanics, canonical transformations, integrable systems, Hamilton-Jacobi equation.</td>
<td></td>
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</table>
J. Lengler

Provide insightful knowledge about the classical theory of curves and surfaces (which is the precursor of modern differential geometry).

Introduction to basic notions and results of group, ring and field

Partial lecture notes are available from Prof. Lang's website https://people.math.ethz.ch/~lang/

- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- Karpfinger-Meyberg: Algebra, Spektrum Verlag

2V+1U

Introduction to differential geometry and differential topology. Contents: Curves, (hyper-)surfaces in R^n, geodesics, curvature, Theorema Egregium, Theorem of Gauss-Bonnet. Hyperbolic space. Differentiable manifolds, immersions and embeddings, Sard’s Theorem, mapping degree and intersection number, vector bundles, vector fields and flows, differential forms, Stokes’ Theorem.

Literature

- S. Bosch: Algebra, Springer Verlag
- B.L. van der Waerden: Algebra I und II, Springer Verlag
- S. Lang, Algebra, Springer Verlag
- A. Knapp: Basic Algebra, Springer Verlag
- J.F. Humphreys: A Course in Group Theory (Oxford University Press)
- G. Smith and O. Tabachnikova: Topics in Group Theory (Springer-Verlag)
- M. Artin: Algebra (Birkhaeuser Verlag)

Core Courses

Core Courses: Pure Mathematics

401-3531-00L Differential Geometry I

At most one of the three course units (Bachelor Core Courses)

401-3461-00L Functional Analysis I

401-3531-00L Differential Geometry I

401-3601-00L Probability Theory

can be recognised for the Master's degree in Mathematics or Applied Mathematics. In this case, you cannot change the category assignment by yourself in myStudies but must take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

Abstract

Introduction to differential geometry and differential topology. Contents: Curves, (hyper-)surfaces in R^n, geodesics, curvature, Theorema Egregium, Theorem of Gauss-Bonnet. Hyperbolic space. Differentiable manifolds, immersions and embeddings, Sard’s Theorem, mapping degree and intersection number, vector bundles, vector fields and flows, differential forms, Stokes’ Theorem.

Objective

Provide insightful knowledge about the classical theory of curves and surfaces (which is the precursor of modern differential geometry).

Invite students to use and sharpen their geometric intuition.

Introduce the language, basic tools, and some fundamental results in modern differential geometry.

Lecture notes

Partial lecture notes are available from Prof. Lang's website https://people.math.ethz.ch/~lang/

- Manfredo P. do Carmo: Differential Geometry of Curves and Surfaces
- John M. Lee: Introduction to Smooth Manifolds
- S. Montiel, A. Ros: Curves and Surfaces
- S. Kobayashi: Differential Geometry of Curves and Surfaces
- Wolfgang Kühnel: Differentialgeometrie, Kurven-Flächen-Mannigfaltigkeiten
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds
- Dennis Barden & Charles Thomas: An Introduction to Differential Manifolds
- A. Manfredo: Differential Geometry of Curves and Surfaces
- A. Knapp: Basic Algebra, Springer Verlag
- J.F. Humphreys: A Course in Group Theory (Oxford University Press)
- G. Smith and O. Tabachnikova: Topics in Group Theory (Springer-Verlag)
- M. Artin: Algebra (Birkhaeuser Verlag)

401-3461-00L Functional Analysis I

At most one of the three course units (Bachelor Core Courses)

401-3461-00L Functional Analysis I

401-3531-00L Differential Geometry I

401-3601-00L Probability Theory

can be recognised for the Master's degree in Mathematics or Applied Mathematics. In this case, you cannot change the category assignment by yourself in myStudies but must take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

Abstract

Introduction: RAM machine, data structures; Algorithms: sorting, median, matrix multiplication, shortest paths, minimal spanning trees; Paradigms: divide & conquer, dynamic programming, greedy algorithms; Data Structures: search trees, dictionaries, priority queues; Complexity Theory: P and NP, NP-completeness, Cook’s theorem, reductions, cryptography and zero-knowledge proofs.

Objective

After this course students know some basic algorithms as well as underlying paradigms. They will be familiar with basic notions of complexity theory and can use them to classify problems.

Content


Lecture notes

Ja.

Autumn Semester 2021
received the credits.

Abstract
Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed range theorem; spectral theory of self-adjoint operators in Hilbert spaces.

Objective
Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature
Recommended references include the following:


Prerequisites / notice
Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH (most remarkably: fluency with topology and measure theory, in part: Lebesgue integration and L^p spaces).

401-3001-61L
Algebraic Topology I

Abstract
This is an introductory course in algebraic topology, which is the study of algebraic invariants of topological spaces. Topics covered include:


Literature

Prerequisites / notice
Useful to have (though not absolutely necessary) basic knowledge of the fundamental group and covering spaces (at the level covered in the course "topology").

Some knowledge of differential geometry and differential topology is useful but not strictly necessary.

Some (elementary) group theory and algebra will also be needed.

401-3132-00L
Commutative Algebra

Abstract
This course provides an introduction to commutative algebra. It serves in particular as a foundation for modern algebraic geometry.

The topics presented in the course will include:

* Basics facts about rings, ideals and modules
* Constructions of rings: quotients, polynomial rings, localization
* Noetherian rings and modules
* The tensor product of modules over commutative rings and its applications
* Krull dimension
* Integral extensions and the Cohen-Seidenberg theorems
* Finitely generated algebras over fields, including the Noether Normalization Theorem and the Nullstellensatz
* Primary decomposition
* Discrete valuation rings and some applications

Literature

Secondary References:
4. "Commutative Algebra" by N. Bourbaki

Prerequisites / notice
Prerequisites: Algebra III/II (or a similar introduction to the basic concepts of ring theory, including field theory).

Core Courses: Applied Mathematics and Further Appl.-Oriented Fields

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<tr>
<td>401-3651-00L</td>
<td>Numerical Methods for Elliptic and Parabolic Partial Differential Equations (University of Zurich)</td>
<td>W</td>
<td>9</td>
<td>6G</td>
<td>S. Sauter</td>
</tr>
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</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: MAT802
Abstract
This course gives a comprehensive introduction into the numerical treatment of linear and nonlinear elliptic boundary value problems, related eigenvalue problems and linear, parabolic evolution problems. Emphasis is on theory and the foundations of numerical methods. Practical exercises include MATLAB implementations of finite element methods.

Objective
Participants of the course should become familiar with
- concepts underlying the discretization of elliptic and parabolic boundary value problems
- analytical techniques for investigating the convergence of numerical methods for the approximate solution of boundary value problems
- methods for the efficient solution of discrete boundary value problems
- implementational aspects of the finite element method

Content
The course will address the mathematical analysis of numerical solution methods for linear and nonlinear elliptic and parabolic partial differential equations. Functional analytic and algebraic (De Rham complex) tools will be provided. Primal, mixed and nonstandard (discontinuous Galerkin, Virtual, Trefftz) discretizations will be analyzed.

Particular attention will be placed on developing mathematical foundations (Regularity, Approximation theory) for a-priori convergence rate analysis. A-posteriori error analysis and mathematical proofs of adaptivity and optimality will be covered. Implementations for model problems in MATLAB and python will illustrate the theory.

A selection of the following topics will be covered:
- Elliptic boundary value problems
- Galerkin discretization of linear variational problems
- The primal finite element method
- Mixed finite element methods
- Discontinuous Galerkin Methods
- Boundary element methods
- Spectral methods
- Adaptive finite element schemes
- Singularly perturbed problems
- Sparse grids
- Galerkin discretization of elliptic eigenproblems
- Non-linear elliptic boundary value problems
- Discretization of parabolic initial boundary value problems

Literature


Additional Literature:
D. Braess: Finite Elements, THIRD Ed., Cambridge Univ. Press, (2007). (Also available in German.)


Prerequisites / notice
Former title of the course unit: Numerical Methods for Elliptic and Parabolic Partial Differential Equations

401-3601-00L Probability Theory
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<th>4V+1U</th>
<th>W. Werner</th>
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<tr>
<td>401-3461-00L Functional Analysis I</td>
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<td>401-3531-00L Differential Geometry I</td>
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<tr>
<td>401-3601-00L Probability Theory</td>
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</table>

Abstract
Basics of probability theory and the theory of stochastic processes in discrete time
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, series of independent random variables, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Lecture notes will be available in electronic form.

**Literature**
- H. Bauer, Probability Theory, de Gruyter 1996
- J. Jacob and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

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<tr>
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<td>Fundamentals of Mathematical Statistics</td>
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<td>S. van de Geer</td>
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<td>4V+2U</td>
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<td>401-3622-00L</td>
<td>Statistical Modelling</td>
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<td>4G</td>
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<td>C. Heinze-Deml</td>
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<tr>
<td>252-0057-00L</td>
<td>Theoretical Computer Science</td>
<td>7</td>
<td>4V+2U</td>
<td></td>
<td></td>
<td>J. Hromkovic, H.-J. Böckenhauer</td>
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### Objective

The course covers the basics of inferential statistics.

### Content

- Key topics include:
  - Linear programming and polyhedra;
  - Flows and cuts;
  - Combinatorial optimization problems and polyhedral techniques;
  - Equivalence between optimization and separation.

### Lecture notes

### Literature


### Taught competencies

#### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

#### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

#### Domain C - Social Competencies
- Project Management: not assessed
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

#### Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Critical Thinking: assessed
- Creative Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

### Prerequisites

- Former course title: Mathematical Optimization.
- Solid background in linear algebra.

### Credits

- 7 credits
- 8 credits
- 10 credits
- 11 credits

### Autumn Semester 2021

- Self-direction and Self-management
- Self-awareness and Self-reflection
- Sensitivity to Diversity
- Critical Thinking
- Negotiation
- Adaptability and Flexibility
- Self-direction and Self-management
- Analytical Competencies
- Project Management
- Understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

### Former course title

252-0057-00L Theoretical Computer Science

This is the course unit with former course title "Regression".

Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).

### Abstract

In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.
This lecture gives an introduction to theoretical computer science, presenting the basic concepts and methods of computer science in its historical context. We present computer science as an interdisciplinary science which, on the one hand, investigates the border between the possible and the impossible and the quantitative laws of information processing, and, on the other hand, designs, analyzes, verifies, and implements computer systems.

The main topics of the lecture are:
- alphabets, words, languages, measuring the information content of words, representation of algorithmic tasks
- finite automata, regular and context-free grammars
- Turing machines and computability
- complexity theory and NP-completeness
- design of algorithms for hard problems

Lecture notes
The lecture is covered in detail by the textbook "Theoretical Computer Science".

Literature

Further reading:

More exercises and examples in:
6. A. Asteroth, Ch. Baier: Theoretische Informatik

Prerequisites / notice
During the semester, two non-obligatory test exams will be offered.

Autumn Semester 2021
Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories | Assessed
Techniques and Technologies | Not Assessed

Domain B - Method-specific Competencies

Analytical Competencies | Assessed
Decision-making | Not Assessed
Media and Digital Technologies | Not Assessed
Problem-solving | Assessed
Project Management | Not Assessed

Domain C - Social Competencies

Communication | Not Assessed
Cooperation and Teamwork | Not Assessed
Customer Orientation | Not Assessed
Leadership and Responsibility | Not Assessed
Self-presentation and Social Influence | Not Assessed
Sensitivity to Diversity | Not Assessed
Negotiation | Not Assessed

Domain D - Personal Competencies

Adaptability and Flexibility | Not Assessed
Creative Thinking | Assessed
Critical Thinking | Not Assessed
Integrity and Work Ethics | Not Assessed
Self-awareness and Self-reflection | Not Assessed
Self-direction and Self-management | Not Assessed

Electives

Selection: Algebra, Number Thy, Topology, Discrete Mathematics, Logic

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<tr>
<td>401-3059-00L</td>
<td>Combinatorics II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
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<td>Abstract</td>
<td>The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.</td>
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<tr>
<td>Objective</td>
<td>Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.</td>
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<tr>
<td>Content</td>
<td>Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler's function, Cayley graphs, formal power series, permutation groups, cycles, Bunsides's lemma, cycle index, Polya's theorems, applications to graph theory and isomers.</td>
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<th>L. Halbeisen</th>
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<td>Die Vorlesung besteht aus drei Teilen:</td>
<td></td>
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<td></td>
<td>Teil I gibt eine Einführung in die Syntax und Semantik der Prädikatenlogik erster Stufe.</td>
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<td>Teil III behandelt die Gödel'schen Unvollständigkeitssätze</td>
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<tr>
<td>Objective</td>
<td>Das Ziel dieser Vorlesung ist ein fundiertes Verständnis der Grundlagen der Mathematik zu vermitteln.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Syntax und Semantik der Prädikatenlogik</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Gödel'scher Vollständigkeitssatz</td>
<td></td>
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<tr>
<td></td>
<td>Gödel'sche Unvollständigkeitssätze</td>
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</tbody>
</table>

Selection: Geometry

<table>
<thead>
<tr>
<th>Number</th>
<th>Finite Geometries II</th>
<th>W</th>
<th>4</th>
<th>2G</th>
<th>N. Hungerbühler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Finite geometries I, II: Students will be able to construct and analyse models of finite geometries. They are familiar with closing theorems of the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Finite geometries I, II: finite fields, rings of polynomials, finite affine planes, axioms of incidence, Euler's thirty-six officers problem, design of statistical tests, orthogonal Latin squares, transformation of finite planes, closing theorems of Desargues and Pappus-Pascal, hierarchy of closing theorems, finite coordinate planes, division rings, finite projective planes, duality principle, finite Möebius planes, error correcting codes, block design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Max Jeger, Endliche Geometrien, ETH Skript 1988</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Albrecht Beutelspacher: Einführung in die endliche Geometrie I,II. Bibliographisches Institut 1983</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press</td>
<td></td>
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<tr>
<td></td>
<td>Dembowski: Finite Geometries.</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Coxeter Groups from a Geometric Viewpoint</th>
<th>W</th>
<th>4</th>
<th>2V</th>
<th>M. Corde</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Introduction to Coxeter groups and the spaces on which they act.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Understand the basic properties of Coxeter groups.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Brown, Kenneth S. &quot;Buildings&quot;</td>
<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Students must have taken a first course in algebraic topology or be familiar with fundamental groups and covering spaces. They should also be familiar with groups and group actions.</td>
<td></td>
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</tr>
</tbody>
</table>

Selection: Analysis

No offering in this semester yet

Selection: Numerical Analysis

No offering in this semester yet
The course offers an introduction into analyzing time series, that is observations which occur in time. The material will cover Stationary Processes, ARMA, ARIMA, Introduction into GARCH models. Does not take place this semester.

The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis. ISBN 978-3-642-20191-2.

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

### Selection: Probability Theory, Statistics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3627-00L</td>
<td>High-Dimensional Statistics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. L. Bühlmann</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>&quot;High-Dimensional Statistics&quot; deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>Knowledge of methods and basic theory for high-dimensional statistical inference</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).</td>
</tr>
<tr>
<td>401-4623-00L</td>
<td>Time Series Analysis</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>F. Balabdaoui</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>The course offers an introduction into analyzing time series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>The goal of the course is to have a a good overview of the different types of time series and the approaches used in their statistical analysis.</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.</td>
</tr>
<tr>
<td></td>
<td><strong>Literature</strong></td>
<td></td>
<td></td>
<td></td>
<td>The key topics which will be covered as: Stationarity, Autocorrelation, Trend estimation, Elimination of seasonality, Spectral analysis, spectral densities, Forecasting, ARMA, ARIMA, Introduction into GARCH models</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>Basic knowledge in probability and statistics</td>
</tr>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
<td></td>
<td></td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power,</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
<td></td>
<td></td>
<td></td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.</td>
</tr>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
<td></td>
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<td></td>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
</tr>
<tr>
<td></td>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
</tr>
<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td></td>
<td>The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
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<td></td>
<td>A script will be available.</td>
</tr>
<tr>
<td>401-0654-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Dettling</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td><strong>Literature</strong></td>
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<td>The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.</td>
</tr>
<tr>
<td></td>
<td><strong>Prerequisites / notice</strong></td>
<td></td>
<td></td>
<td></td>
<td>A script will be available.</td>
</tr>
</tbody>
</table>

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3623-00L "Statistical Modelling" are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.
## Taught competencies

### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

### Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Self-influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

### Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Self-reflection: not assessed
- Self-awareness and Self-management: not assessed

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### 401-3628-14L Bayesian Statistics

**Abstract**

Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

**Objective**

Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

**Content**

Topics that we will discuss are:

- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods).

**Lecture notes**

A script will be available in English.

**Literature**


**Prerequisites / notice**

Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

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### Selection: Financial and Insurance Mathematics

In the Bachelor's programme in Mathematics 401-3913-01L Mathematical Foundations for Finance is eligible as an elective course, but only if 401-3888-00L Introduction to Mathematical Finance isn’t recognised for credits (neither in the Bachelor’s nor in the Master's programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3922-00L</td>
<td>Life Insurance Mathematics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Koller</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.</td>
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</tbody>
</table>

| 401-3925-00L | Non-Life Insurance: Mathematics and Statistics | W    | 8    | 4V+1U | M. V. Wüthrich |
| **Abstract** | The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency. |
| **Objective** | The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations. |
| **Content** | The following topics are treated: Collective Risk Modeling, Individual Claim Size Modeling, Approximations for Compound Distributions, Ruin Theory in Discrete Time, Premium Calculation Principles, Tariffication, Generalized Linear Models and Neural Networks, Bayesian Models and Credibility Theory, Claims Reserving, Solvency Considerations |
| **Prerequisites / notice** | The exams ONLY take place during the official ETH examination period. This course will be held in English and counts towards the diploma of “Aktuar SAV”. For the latter, see details under www.actuaries.ch. Prerequisites: knowledge of probability theory, statistics and applied stochastic processes.
Abstract
In life insurance, it is essential to have adequate mortality tables, be it for reserving or pricing purposes. The course provides the tools necessary to create mortality tables from scratch. Additionally, we study various guarantees embedded in life insurance products and learn to price them with the help of stochastic models.

Objective
The course's objective is to provide the students with the understanding and the tools to create mortality tables on their own. Additionally, students should learn to price embedded options in life insurance. Aside of the mere application of specific models, they should develop an intuition for the various drivers of the value of these options.

Content
Following main topics are covered:

1. Guarantees and options embedded in life insurance products.
   - Stochastic valuation of participating contracts
   - Stochastic valuation of Unit Linked contracts
2. Mortality Tables:
   - Determining raw mortality rates
   - Smoothing techniques: Whittaker-Henderson, smoothing splines,...
   - Trends in mortality rates
   - Stochastic mortality model due to Lee and Carter
   - Neural Network extension of the Lee-Carter model
   - Integration of safety margins

Lecture notes
Lectures notes and slides will be provided.

Prerequisites / notice
The exams ONLY take place during the official ETH examination period.

The course counts towards the diploma of "Aktuar SAV".

Good knowledge in probability theory and stochastic processes is assumed. Some knowledge in financial mathematics is useful.


Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. While in the past many of the basic combinatorial results were obtained mainly by ingenuity and detailed reasoning, the modern theory has grown out of this early stage and often relies on deep, well-developed tools.

One of the main general techniques that played a crucial role in the development of Combinatorics was the application of algebraic methods. The most fruitful such tool is the dimension argument. Roughly speaking, the method can be described as follows. In order to bound the cardinality of a discrete structure A one maps its elements to vectors in a linear space, and shows that the set A is mapped to linearly independent vectors. It then follows that the cardinality of A is bounded by the dimension of the corresponding linear space. This simple idea is surprisingly powerful and has many famous applications.

This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods.
- Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem.
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

Lecture notes: Lectures will be on the blackboard only, but there will be a set of typed lecture notes which follow the class closely. Students are expected to have a mathematical background and should be able to write rigorous proofs.

**Selection: Mathematical Physics, Theoretical Physics**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0830-00L</td>
<td>General Relativity</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>C. Anastasiou</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.

**Objective**

Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).

**Content**

Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

**Literature**

Suggested textbooks:
- C. Misner, K. Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- R. Wald - General Relativity
- S. Weinberg - Gravitation and Cosmology

**Selection: Mathematical Optimization, Discrete Mathematics**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3055-64L</td>
<td>Algebraic Methods in Combinatorics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>B. Sudakov</td>
</tr>
</tbody>
</table>

**Abstract**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**

The students will get an overview of various algebraic methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to Algebraic methods, illustrated by examples and focusing on basic ideas and connections to other areas. The topics covered in the class will include (but are not limited to):

- Basic dimension arguments, Spaces of polynomials and tensor product methods.
- Eigenvalues of graphs and their application, the Combinatorial Nullstellensatz and the Chevalley-Warning theorem.
- Applications such as: Solution of Kakeya problem in finite fields, counterexample to Borsuk's conjecture, chromatic number of the unit distance graph of Euclidean space, explicit constructions of Ramsey graphs and many others.

The course website can be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15757

**Prerequisites / notice**

Lectures will be on the blackboard only, but there will be a set of typed lecture notes which follow the class closely. Students are expected to have a mathematical background and should be able to write rigorous proofs.

**Auswahl: Theoretical Computer Science**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U+4A</td>
<td>A. Steger</td>
</tr>
</tbody>
</table>
Abstract
Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks

Objective
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.

Content
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Lecture notes
Yes.

Literature

252-1425-00L Geometry: Combinatorics and Algorithms

Abstract
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic questions (Can we find a certain object efficiently?)

Objective
The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains. In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.

Content
Planar and geometric graphs, embeddings and their representation (Whitney's Theorem, canonical orderings, DCEL), polygon triangulations and the art gallery theorem, convexity in R^d, planar convex hull algorithms (Jarvis Wrap, Graham Scan, Chan's Algorithm), point set triangulations, Delaunay triangulations (Lawson flips, lifting map, randomized incremental construction), Voronoi diagrams, the Crossing Lemma and incidence bounds, line arrangements (duality, Zone Theorem, ham-sandwich cuts), 3-SUM hardness, counting planar triangulations.

Lecture notes
Yes.

Literature

Prerequisites / notice
Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH.

Selection: Further Realms

Autumn Semester 2021

0401-3502-71L Reading Course ■

To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/mathdepartment/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3503-71L Reading Course ■

To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/mathdepartment/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-71L Reading Course ■

To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/mathdepartment/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.
Communication in Mathematics

Does not take place this semester.

Abstract

Don't hide your Next Great Theorem behind bad writing.

Objective

Knowing how to present written mathematics in a structured and clear manner.

Content

Topics covered include:

- Language conventions and common errors.
- How to write a thesis (more generally, a mathematics paper).
- How to use LaTeX.
- How to write a personal statement for Masters and PhD applications.

Lecture notes

Full lecture notes will be made available on my website:

https://www.merry.io/teaching/

Prerequisites / notice

There are no formal mathematical prerequisites.

Core Courses and Electives (Mathematics Master)

Core Courses (Mathematics Master)

Electives (Mathematics Master)

Seminars

NOTICE: The number of seminar places is limited, and the special selection procedure should help to allocate the places not primarily according to the registration time. Everybody is waitlisted first when he/she tries to register for a seminar in myStudsys.

Moreover: Only one mathematics seminar can be chosen per semester.

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
401-3050-71L | Student Seminar in Combinatorics | W | 4 credits | 2S | B. Sudakov
401-3110-71L | Student Seminar in Elementary Number Theory | W | 4 credits | 2S | Ö. Imamoglu
401-3100-71L | Student Seminar in Number Theory: L-Functions | W | 4 credits | 2S | M. Schwagenscheidt
401-3550-71L | Student Seminar in Topological Data Analysis | W | 4 credits | 2S | S. Kalisnik Hintz
401-3140-71L | Student Seminar in Algebraic Geometry: Complex Algebraic Surfaces | W | 4 credits | 2S | T.-H. Bülles, R. Pandharipande

Literature

- Topological Methods for the Analysis of High Dimensional Data Sets and 3D Object Recognition, G. Singh, F. Memoli, G. Carlsson, Proceedings of the National Academy of Sciences 108 (17), 7265-7270
- Zigzag persistence, G. Carlsson, V. De Silva, Foundations of computational mathematics 10 (4), 367-405
Linear regression is one of the most used models for prediction and hence one of the most understood in statistical literature. However, we will see how techniques of algebraic geometry are applied to classify complex algebraic surfaces. Along the way we discuss invariants Concepts and Theories

The main goal is the students get to discover some less known regression models which either generalize the well-known linear model (for example monotone regression) or violate some of the most fundamental assumptions (as in shuffled or unlinked regression models).

In the following is the tentative material that will be read and studied by each pair of students (all the items listed below are available through the ETH electronic library or arXiv). Some of the items might change.

8. "Linear regression with shuffled data: statistical and computation limits of permutation recovery" by A. Pananjady, M. Wainwright and T. A. Courtade, 2018, IEEE transactions in Information Theory, Volume 64, 3286-3300
9. "Linear regression without correspondence" by D. Hsu, K. Shi and X. Sun, 2017, NIPS
10. "Uncoupled isotonic regression via minimum Wasserstein deconvolution" by P. Rigollet and J. Weed, 2019, Information and Inference, Volume 00, 1-27

The students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

Seminar (Mathematics Master)

Die Student*Innen sind vertraut mit der Teilertheorie, Primfaktorzerlegung, und Faktorringen der ganzen und Gauss'schen Zahlen.

Die Student*Innen sind in der Lage zu bestimmen ob zwei binäre quadratische Formen zueinander SL_2(Z)-äquivalent sind und ob eine gegebene ganze Zahl durch eine binäre quadratische Form einer gegebenen Diskriminante repräsentierbar ist mittels dem Legendre Symbol und quadratischer Reziprozität. Studierende sind auch in der Lage den zwei Quadratesatz mittels binären quadratischen Formen zu beweisen.


Ganz anders sieht es aus bei den binären quadratischen Formen, wo man beliebige Formen der gleichen Diskriminante multiplizieren kann. Ferner wird ein wenig in die Repräsentationstheorie jener Formen eingegangen und damit zusammenhängend auch das Legendre symbol und quadratische Reziprozität besprochen.

Literatur
- D. A. Cox: Primes of the form x^2+ny^2
- A. R. Rajwade: Squares
- J. Voight: Quaternion algebras
- F. Lemmermeyer: Binary Quadratic Forms
- S. Bosch: Algebra

Prerequisites / notice
- Linear Algebra, Analysis, Algebra I (im Parallelen)

Bachelor’s Thesis

Scientific Works in Mathematics

Target audience:
- Third year Bachelor students;
- Master students who cannot document to have received an adequate training in working scientifically.

Objective
Learn the basic standards of scientific works in mathematics.

Content
- Types of mathematical works
- Publication standards in pure and applied mathematics
- Data handling
- Ethical issues
- Citation guidelines

Abstract
Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)

Prerequisites / notice

Bachelor’s Thesis

Lunch Sessions – Thesis Basics for Mathematics

Details and registration for the optional MathBib training course: https://www.math.ethz.ch/mathbib-schulungen

Abstract
Optional MathBib training course

Bachelor’s Thesis

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required.

For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Abstract
The purpose of the BSc thesis is to deepen knowledge in a certain subject chosen by the student. In their BSc thesis, students should demonstrate their ability to carry out independent work in mathematics and to organize results in a written report.

GESS Science in Perspective

Science in Perspective

Recommended Science in Perspective (Type B) for D-MATH.

Language Courses

Additional Courses
**401-5000-00L** Zurich Colloquium in Mathematics  
**401-5990-00L** Zurich Graduate Colloquium

**Abstract**  
The Graduate Colloquium is an informal seminar aimed at graduate students and postdocs whose purpose is to provide a forum for communicating one's interests and thoughts in mathematics.

**401-5960-00L** Colloquium on Mathematics, Computer Science, and Education  
Subject didactics for mathematics and computer science teachers.

**Abstract**  
Didactics colloquium

**402-0101-00L** The Zurich Physics Colloquium

**Abstract**  
Research colloquium

**402-0800-00L** The Zurich Theoretical Physics Colloquium

**Objective**  
The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

**251-0100-00L** Computer Science Colloquium

**Abstract**  
Invited talks, covering the entire scope of computer science. External Listeners are welcome at no charge. A detailed schedule is published at the beginning of each semester.

**Objective**  
Top international computer scientists take the floor at the distinguished computer science colloquium. Our guest speakers present impacting topics across various areas of the discipline. The colloquium series is held every semester and also includes inaugural and farewell lectures of the department's professors. The colloquium is a noteworthy event for all graduate students. Outside attendance is equally welcome.

**Mathematics Bachelor - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
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</table>

**Key for Hours**

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Mathematics TC

Detailed information on the programme at: www.ethz.ch/didaktische-ausbildung

► Educational Science

General course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

see Educational Science TC

► Subject Didactics and Professional Training

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

Enrolment in either Mathematics Didactics I or Mathematics Didactics II (spring semester) is compulsory.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3971-11L</td>
<td>Mathematics Didactics I</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>A. Barth</td>
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<tr>
<td></td>
<td>Enrolment only possible with matriculation in Mathematics</td>
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</tr>
<tr>
<td></td>
<td>Teaching Diploma or Mathematics TC at ETH or in</td>
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</tr>
<tr>
<td></td>
<td>Mathematics Teaching Diploma at UZH.</td>
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</tbody>
</table>

Abstract

Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching various topics in mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

Objective

- To be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- To show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.
- They learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching various topics in mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

Enrolment only possible with matriculation in Mathematics Teaching Diploma at UZH.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-9987-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>4</td>
<td>9P</td>
<td>N. Hungerbühler</td>
</tr>
<tr>
<td></td>
<td>Mathematics for TC</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Repetition of the Teaching Internship is excluded even if</td>
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<tr>
<td></td>
<td>Examination Lessons are to be repeated.</td>
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</tbody>
</table>

Abstract

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Objective

- Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
- On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

Enrolment only possible with matriculation in Mathematics Teaching Diploma at UZH.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-9983-00L</td>
<td>Mentored Work Subject Didactics Mathematics A</td>
<td>O</td>
<td>2</td>
<td>4A</td>
<td>M. Akveld, K. Barro, A. Barth, L. Halbeisen, N. Hungerbühler, C. Rüede</td>
</tr>
<tr>
<td></td>
<td>Mentored Work Subject Didactics in Mathematics for TC</td>
<td></td>
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<tr>
<td></td>
<td>and Teaching Diploma.</td>
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</tbody>
</table>

Abstract

- Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
- On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

Objective

- Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are as assessed as Examination Lessons.
- On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating learning arrangements, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

Enrolment only possible with matriculation in Mathematics Teaching Diploma at UZH.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-3057-00L</td>
<td>Finite Geometries II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
<td></td>
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<td></td>
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</tbody>
</table>

Autumn Semester 2021
Page 1587 of 2152
## Abstract


## Objective


## Content


## Literature

- Albrecht B. Einführung in die endliche Geometrie I, II. Bibliographisches Institut 1983
- Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press
- Hubert Stanley: Finite Geometries.
- Dambowski: Finite Geometries.
Objective

The aim is for the students
- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content

Thematische Schwerpunkte:

Lernformen:

Lecture notes
Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature
Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice
Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

Colloquia

| Number      | Title                                                                 | Type | ECTS  | Hours | Lecturers                        |
|-------------|                                                                      |      |       |       |                                 |
| 401-5960-00L| Colloquium on Mathematics, Computer Science, and Education Subject didactics for mathematics and computer science teachers. | E-   | 0 credits |       | N. Hungerbühler, M. Akveld, D. Grawehr Morath, J. Hromkovic, P. Spindler |

Abstract

Didactics colloquium

Mathematics TC - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Die Literatur ist themenspezifisch. Die Studierenden beschaffen sie sich in der Regel selber (siehe Lernziele). In besonderen Fällen wird

#### Unterrichtliche Schwerpunkte

**Number** 401-9984-00L  
**Title** Mentored Work Subject Didactics Mathematics B  
**Type** O  
**ECTS** 2 credits  
**Hours** 4A  
**Lecturers** M. Akveld, K. Barro, A. Barth, L. Halbeisen, N. Hungerbühler, C. Rüede

**Abstract**  
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Objective**  
The objective is for the students:  
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.  
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

**Content**  
Thematische Schwerpunkte  
Die Gegenstände der mentorierten Arbeit in Fachdidaktik stammen in der Regel aus dem gymnasialen Unterricht.

Lernformen  

**Prerequisites / notice**  
Die Art der mentorierten Arbeit wird zur Verfügung gestellt.

#### Professional Training in Mathematics

**Number** 401-9970-00L  
**Title** Introductory Internship Mathematics  
**Type** O  
**ECTS** 3 credits  
**Hours** 6P  
**Lecturers** N. Hungerbühler

**Abstract**  
Enrolment only possible with matriculation in Mathematics Teaching Diploma or Mathematics TC at ETH. It is advisable to enrol in this course not prior to the first Mathematics Didactics course and not after the second Mathematics Didactics course.
During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts

Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating teaching plans, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

Widt von der Praktikumslehrperson bestimmt.

**Abstract**

**Objective**

**Content**

Den Studierenden bietet das Einführungspraktikum einen Einblick in den Berufsalltag einer Lehrperson.

**Literature**

Widt von der Praktikumslehrperson bestimmt.

**401-3971-99L**

**Professional Exercises I**

*Enrolment only possible with matriculation in Mathematics Teaching Diploma or Mathematics TC at ETH.*

**Simultaneous enrolment in Mathematics Didactics - course unit 401-3971-11L - is compulsory.

**Abstract**

Students learn about and learn to use findings from empirical research into mathematical didactics and best practice, as well as theoretical approaches to teaching mathematics. Methodological suggestions are compared and draft tuition concepts discussed.

**Objective**

On the basis of their understanding of mathematics, of the knowledge acquired from research into teaching/learning and subject teaching, and also of best practice, students who have completed this course will be in a position to draft motivating teaching plans, with cognitive appeal, which trigger and maintain learning processes. The aim here is to implement a corresponding teaching plan, so that the mathematics tuition that is given has a general-education value, on the one hand, and ensures that pupils acquire the fundamental knowledge necessary for studying at university, on the other hand.

**Prerequisites / notice**

This course is to be chosen jointly with 401-3972-00L.

**401-9988-00L**

**Teaching Internship Mathematics I**

The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

**Abstract**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Objective**

- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

Die Studierenden sammeln Erfahrungen in der Unterrichtsführung, der Auseinandersetzung mit Lernenden, der Klassenbetreuung und der Leistungskontrolle.

**Literature**

Widt von der Praktikumslehrperson bestimmt.

**401-9989-00L**

**Teaching Internship Mathematics II**

This is a supplement to the Teaching Internship required to obtain a Master of Advanced Studies in Secondary and Higher Education in the corresponding subject. It is aimed at enlarging the already acquired teaching experience. Students observe 10 lessons and teach 15 lessons independently.

**Abstract**

The students can estimate the significance of teaching topics in their subject from different perspectives (including interdisciplinary perspectives) and impart these to their pupils.

**Objective**


Lecture notes
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice
Nach Abschluss der übrigen Ausbildung.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-9991-02L</td>
<td>Examination Lesson II Mathematics</td>
<td>O</td>
<td>1</td>
<td>2P</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract
Simultaneous enrolment in "Examination Lesson I Mathematics" (401-9991-01L) is compulsory.

Objective
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Content

Die gehaltene Lektion wird kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltene Lektion im Rahmen eines kurzen Kolloquiums.

Lecture notes
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice
Nach Abschluss der übrigen Ausbildung.


<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3059-00L</td>
<td>Combinatorics II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract
The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.

Objective
Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

Content
Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler's function, Cayley graphs, formal power series, permutation groups, cycles, Bunsdie's lemma, cycle index, Polya's theorems, applications to graph theory and isomers.

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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3057-00L</td>
<td>Finite Geometries II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Abstract
Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

Objective
Finite geometries I, II: Students will be able to construct and analyse models of finite geometries. They are familiar with closing theorems of the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.

Content
Finite geometries I, II: finite fields, rings of polynomials, finite affine planes, axioms of incidence, Euler's thirty-six officers problem, design of statistical tests, orthogonal Latin squares, transformation of finite planes, closing theorems of Desargues and Pappus-Pascal, hierarchy of closing theorems, finite coordinate planes, division rings, finite projective planes, duality principle, finite Moebius planes, error correcting codes, block design

Literature
- Max Jeger, Endliche Geometrien, ETH Skript 1988
- Albrecht Beutelspacher: Einführung in die endliche Geometrie I,II. Bibliographisches Institut 1983
- Margaret Lynn Batten: Combinatorics of Finite Geometries. Cambridge University Press
- Dembowski: Finite Geometries.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-0293-00L</td>
<td>Mathematics III</td>
<td>W</td>
<td>5</td>
<td>3V+2U</td>
<td>E. W. Farkas</td>
</tr>
</tbody>
</table>

Abstract
Vertiefung der mehrdimensionalen Analysis mit Schwerpunkt in der Anwendung der partiellen Differentialgleichungen, Vertiefung der Linearer Algebra und Einführung in die Systemanalyse und Modellbildung.

Objective
Vertiefung und Ausbau des Stoffes der Vorlesungen Mathematik I/II für die Anwendung in der Systemanalyse.
Systeme linearer Differentialgleichungen 1. Ordnung

- Definition, allgemeine Lösungsmenge, Fundamentalsystem
- Bestimmung von Lösungen mittels Eigenvektoren, Fundamentalsystem im diagonalisierbaren Fall
- Exponential einer Matrix
- homogene lineare Differentialgleichungen n-ter Ordnung mit konstanten Koeffizienten.

Mathematische Modelle

- Begriffsbildung: (mathematisches) Modell, einführende Beispiele
- Lineare Kompartment-Modelle (Box-Modelle)

Laplace-Transformation

- Grundbegriffe: Definition der Laplace-Transformation und Rücktransformation, Konvergenz des Laplace-Integrals
- Eigenschaften der Laplace-Transformation
- Anwendungen der Laplace-Transformation zur Lösung linearer Differentialgleichungen mit konstanten Koeffizienten.

Partielle Differentialgleichungen

- Definition, Randbedingungen, Anfangsbedingungen
- Diffusionsgleichung: Herleitung, Lösung an einfachen Beispielen
- Techniken: Separationsansätze, Basislösungen, Superpositionsprinzip
- Laplace-Gleichung: Lösung einfacher Randwertprobleme, Polarmodell, Poisson-Formel, harmonische Funktionen.

Lecture notes

Siehe Lernmaterial > Literatur

Literature

- Papula, L., Mathematik für Ingenieure und Naturwissenschaftler, Band 2, Vieweg und Teubner (2015), Kapitel 2 über Fourierreihen und Kapitel 4 über Partielle Differentialgleichungen
- A'Campo-Neuen, A., Skript über Gekoppelte Differentialgleichungen

Prerequisites / notice

Vorlesungen Mathematik I/II

401-9985-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics A

Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Mathematics for TC and Teaching Diploma.

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Objective

- to familiarise themselves with a new topic by obtaining material and studying the sources, so that they can selectively extend their specialist competence in this way.
- to independently develop a text on the topic, with special focus on its mathematical comprehensibility in respect of the level of knowledge of the targeted readership.
- To try out different options for specialist further training in their profession.

Content

Thematische Schwerpunkte:


Lernformen:


Lecture notes

Eine Anleitung zur mentorierten Arbeit in FV wird zur Verfügung gestellt.

Literature

Die Literatur ist themenspezifisch. Sie muss je nach Situation selber beschafft werden oder wird zur Verfügung gestellt.

Prerequisites / notice

Die Arbeit sollte vor Beginn des Praktikums abgeschlossen werden.

401-9986-00L Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Mathematics B

Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Mathematics for Teaching Diploma and for students upgrading TC to Teaching Diploma.

Abstract

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

Compulsory Elective Courses

Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".
The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value for mathematics classes. The course covers the didactics of logic, of cryptography, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

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The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

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The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

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### Mathematics Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

### Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS** European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Mathematics Master

Core Courses

For the Master's degree in Applied Mathematics the following additional condition (not manifest in myStudies) must be obeyed: At least 15 of the required 28 credits from core courses and electives must be acquired in areas of applied mathematics and further application-oriented fields.

Core Courses: Pure Mathematics

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3225-00L</td>
<td>Introduction to Lie Groups</td>
<td>W</td>
<td>8 credits</td>
<td>4G</td>
<td>A. Iozzi</td>
</tr>
<tr>
<td>Abstract</td>
<td>Topological groups and Haar measure. Definition of Lie groups, examples of local fields and examples of discrete subgroups; basic properties; Lie subgroups. Lie algebras and relation with Lie groups: exponential map, adjoint representation. Semisimplicity, nilpotency, solvability, compactness: Killing form, Lie's and Engel's theorems. Definition of algebraic groups and relation with Lie groups.</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The goal is to have a broad though foundational knowledge of the theory of Lie groups and their associated Lie algebras with an emphasis on the algebraic and topological aspects of it.</td>
<td></td>
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</tr>
</tbody>
</table>
| Literature   | A. Knapp: "Lie groups beyond an Introduction" (Birkhäuser)  
F. Warner: "Foundations of differentiable manifolds and Lie groups" (Springer)  
H. Samelson: "Notes on Lie algebras" (Springer, '90)  
S. Helgason: "Differential geometry, Lie groups and symmetric spaces" (Academic Press, '78)  

Prerequisites / notice

Topology and basic notions of measure theory. A basic understanding of the concepts of manifold, tangent space and vector field is useful, but could also be achieved throughout the semester.

Course webpage: https://metaphor.ethz.ch/x/2018/hs/401-3225-00L/

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>401-3001-61L</td>
<td>Algebraic Topology I</td>
<td>W</td>
<td>8 credits</td>
<td>4G</td>
<td>W. Merry</td>
</tr>
<tr>
<td>Abstract</td>
<td>This is an introductory course in algebraic topology, which is the study of algebraic invariants of topological spaces. Topics covered include: singular homology, cell complexes and cellular homology, the Eilenberg-Steenrod axioms.</td>
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</tbody>
</table>
See also: http://www.math.cornell.edu/~hatcher/#anchor1772800 |
| Prerequisites / notice | Topology and basic notions of measure theory. A basic understanding of the concepts of manifold, tangent space and vector field is useful, but could also be achieved throughout the semester.  
Some knowledge of differential geometry and differential topology is useful but not strictly necessary.  
Some (elementary) group theory and algebra will also be needed. |

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<tbody>
<tr>
<td>401-3132-00L</td>
<td>Commutative Algebra</td>
<td>W</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>E. Kowalski</td>
</tr>
</tbody>
</table>
| Abstract     | This course provides an introduction to commutative algebra. It serves in particular as a foundation for modern algebraic geometry. The topics presented in the course will include:  
* Basics facts about rings, ideals and modules  
* Constructions of rings: quotients, polynomial rings, localization  
* Noetherian rings and modules  
* The tensor product of modules over commutative rings and its applications  
* Krull dimension  
* Integral extensions and the Cohen-Seidenberg theorems  
* Finitely generated algebras over fields, including the Noether Normalization Theorem and the Nullstellensatz  
* Primary decomposition  
* Discrete valuation rings and some applications |
Secondary References:  
4. "Commutative Algebra" by N. Bourbaki |
| Prerequisites / notice | Prerequisites: Algebra III (or a similar introduction to the basic concepts of ring theory, including field theory). |

Core Courses: Applied Mathematics and Further Appl.-Oriented Fields

<table>
<thead>
<tr>
<th>Number</th>
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<tbody>
<tr>
<td>401-3651-00L</td>
<td>Numerical Methods for Elliptic and Parabolic Partial Differential Equations (University of Zurich)</td>
<td>W</td>
<td>9 credits</td>
<td>6G</td>
<td>S. Sauter</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
Abstract

This course gives a comprehensive introduction into the numerical treatment of linear and nonlinear elliptic boundary value problems, related eigenvalue problems and linear, parabolic evolution problems. Emphasis is on theory and the foundations of numerical methods. Practical exercises include MATLAB implementations of finite element methods.

Objective

Participants of the course should become familiar with

- concepts underlying the discretization of elliptic and parabolic boundary value problems
- analytical techniques for investigating the convergence of numerical methods for the approximate solution of boundary value problems
- methods for the efficient solution of discrete boundary value problems
- implementational aspects of the finite element method

Content

The course will address the mathematical analysis of numerical solution methods for linear and nonlinear elliptic and parabolic partial differential equations. Functional analytic and algebraic (De Rham complex) tools will be provided. Primal, mixed and nonstandard (discontinuous Galerkin, Virtual, Trefftz) discretizations will be analyzed. Particular attention will be placed on developing mathematical foundations (Regularity, Approximation theory) for a-priori convergence rate analysis. A-posteriori error analysis and mathematical proofs of adaptivity and optimality will be covered. Implementations for model problems in MATLAB and python will illustrate the theory.

A selection of the following topics will be covered:

- Elliptic boundary value problems
- Galerkin discretization of linear variational problems
- The primal finite element method
- Mixed finite element methods
- Discontinuous Galerkin Methods
- Boundary element methods
- Spectral methods
- Adaptive finite element schemes
- Singularly perturbed problems
- Sparse grids
- Galerkin discretization of elliptic eigenproblems
- Non-linear elliptic boundary value problems
- Discretization of parabolic initial boundary value problems

Literature


Additional Literature:

D. Braess: Finite Elements, THIRD Ed., Cambridge Univ. Press, (2007). (Also available in German.)


Prerequisites / notice

Former title of the course unit: Numerical Methods for Elliptic and Parabolic Partial Differential Equations

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3621-00L</td>
<td>Fundamentals of Mathematical Statistics</td>
<td>10</td>
<td>W</td>
<td>S. van de Geer</td>
</tr>
<tr>
<td>401-3622-00L</td>
<td>Statistical Modelling</td>
<td>8</td>
<td>W</td>
<td>C. Heinze-Deml</td>
</tr>
</tbody>
</table>

Preparatory reading: Fundamentals of Mathematical Statistics, S. van de Geer
**Prerequisites / notice**
This is the course unit with former course title "Regression".
Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).

**401-4889-00L Mathematical Finance**

**W** 11 credits 4V+2U  D. Possamai

**Abstract**
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

**Objective**
Advanced course on mathematical finance, presupposing good knowledge in probability theory and stochastic calculus (for continuous processes).

**Content**
This is an advanced course on mathematical finance for students with a good background in probability. We want to give an overview of main concepts, questions and approaches, and we do this mostly in continuous-time models.

Topics include
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

**Lecture notes**
The course is based on different parts from different books as well as on original research literature.

**Literature**
Lecture notes will not be available.

(Will be updated later)

**Prerequisites / notice**
Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)
Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.


**401-3901-00L Linear & Combinatorial Optimization**

**W** 11 credits 4V+2U  R. Zenklusen

**Abstract**
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

**Literature**

**Prerequisites / notice**
Solid background in linear algebra.

**Taught competencies**

**Domain A - Subject-specific Competencies**

- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Domain C - Social Competencies**

- Communication

**Domain D - Personal Competencies**

- Adaptability and Flexibility
- Negotiation

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### Bachelor Core Courses: Pure Mathematics

Further restrictions apply, but in particular:

401-3531-00L Differential Geometry I can only be recognised for the Bachelor Programme if 401-3532-00L Differential Geometry II has not been recognised for the Bachelor Programme.

Analogously for:

- 401-3461-00L Functional Analysis I
- 401-3462-00L Functional Analysis II
- 401-3001-61L Algebraic Topology I
- 401-3002-12L Algebraic Topology II
- 401-3132-00L Commutative Algebra
- 401-3146-12L Algebraic Geometry

For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>401-3461-00L</td>
<td>Functional Analysis I</td>
<td>E-</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>J. Teichmann</td>
</tr>
<tr>
<td>401-3531-00L</td>
<td>Differential Geometry I</td>
<td>E-</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>J. Serra</td>
</tr>
</tbody>
</table>

### Bachelor Core Courses: Applied Mathematics...

Further restrictions apply, but in particular:

401-3601-00L Probability Theory can only be recognised for the Master Programme if 401-3642-00L Brownian Motion and Stochastic Calculus nor 401-3602-00L Applied Stochastic Processes has been recognised for the Bachelor Programme.

402-0205-00L Quantum Mechanics I is eligible as an applied core course, but only if 402-0224-00L Theoretical Physics (offered for the last time in FS 2016) isn't recognised for credits (neither in the Bachelor's nor in the Master's programme).

For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3601-00L</td>
<td>Probability Theory</td>
<td>E-</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>W. Werner</td>
</tr>
</tbody>
</table>
Abstract
Basics of probability theory and the theory of stochastic processes in discrete time

Objective
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- Basics in measure theory, series of independent random variables, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Content
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:
- Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Lecture notes
will be available in electronic form.

Literature
- H. Bauer, Probability Theory, de Gruyter 1996
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

402-0205-00L Quantum Mechanics I W 10 credits 3V+2U M. Gaberdiel

Abstract

Objective
Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradox and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle, in deutscher Sprache

Literature
- G. Baym, Lectures on Quantum Mechanics
- E. Merzbacher, Quantum Mechanics
- L.I. Schiff, Quantum Mechanics
- R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
- J.J. Sakurai: Modern Quantum Mechanics
- A. Messiah: Quantum Mechanics I
- S. Weinberg: Lectures on Quantum Mechanics

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

For the Master's degree in Applied Mathematics the following additional condition (not manifest in myStudies) must be obeyed: At least 15 of the required 28 credits from core courses and electives must be acquired in areas of applied mathematics and further application-oriented fields.

Electives: Pure Mathematics

Selection: Algebra, Number Thy, Topology, Discrete Mathematics, Logic

401-3059-00L Combinatorics II W 4 credits 2G N. Hungerbüihler

Abstract
The course Combinatorics I and II is an introduction into the field of enumerative combinatorics.

Objective
Upon completion of the course, students are able to classify combinatorial problems and to apply adequate techniques to solve them.

Content
Contents of the lectures Combinatorics I and II: congruence transformation of the plane, symmetry groups of geometric figures, Euler's function, Cayley graphs, formal power series, permutation groups, cycles, Bůnsdie's lemma, cycle index, Polya's theorems, applications to graph theory and isomers.

Autumn Semester 2021
Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular,

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3033-00L</td>
<td>Gödel's Theorems</td>
<td>W</td>
<td>8</td>
<td>3V+1U</td>
<td>L. Halbeisen</td>
</tr>
<tr>
<td>Abstract</td>
<td>Die Vorlesung besteht aus drei Teilen:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Teil I gibt eine Einführung in die Syntax und Semantik der Prädikatenlogik erster Stufe.</td>
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<tr>
<td></td>
<td>Teil II behandelt den Gödel'schen Vollständigkeitssatz</td>
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<tr>
<td></td>
<td>Teil III behandelt den Gödel'schen Unvollständigkeitssätze</td>
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<tr>
<td>Objective</td>
<td>Das Ziel dieser Vorlesung ist ein fundiertes Verständnis der Grundlagen der Mathematik zu vermitteln.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Syntax und Semantik der Prädikatenlogik</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gödel'scher Vollständigkeitssatz</td>
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<tr>
<td></td>
<td>Gödel'sche Unvollständigkeitssätze</td>
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</table>

<<<< Selection: Geometry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3533-70L</td>
<td>Topics in Riemannian Geometry</td>
<td>W</td>
<td>6</td>
<td>2V</td>
<td>U. Lang</td>
</tr>
<tr>
<td>Abstract</td>
<td>Selected topics from Riemannian geometry in the large: triangle and volume comparison theorems, Milnor's results on growth of the fundamental group, Gromov-Hausdorff convergence, Cheeger's diffeomorphism finiteness theorem, the Besson-Courtois-Gallot barycenter method and the proofs of the minimal entropy theorem and the Mostow rigidity theorem for rank one locally symmetric spaces.</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Lecture notes will be provided.</td>
<td></td>
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<tr>
<td>401-4207-71L</td>
<td>Coxeter Groups from a Geometric Viewpoint</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Cordes</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Coxeter groups and the spaces on which they act.</td>
<td></td>
<td></td>
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<tr>
<td>Objective</td>
<td>Understand the basic properties of Coxeter groups.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Brown, Kenneth S. &quot;Buildings&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Davis, Michael &quot;The geometry and topology of Coxeter groups&quot;</td>
<td></td>
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</tr>
<tr>
<td>Literature</td>
<td>Students must have taken a first course in algebraic topology or be familiar with fundamental groups and covering spaces. They should also be familiar with groups and group actions.</td>
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<tr>
<td>401-3057-00L</td>
<td>Finite Geometries II</td>
<td>W</td>
<td>4</td>
<td>2G</td>
<td>N. Hungerbühler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Finite geometries I, II: Finite geometries combine aspects of geometry, discrete mathematics and the algebra of finite fields. In particular, we will construct models of axioms of incidence and investigate closing theorems. Applications include test design in statistics, block design, and the construction of orthogonal Latin squares.</td>
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<tr>
<td>Objective</td>
<td>Finite geometries I, II: Students will be able to construct and analyse models of finite geometries. They are familiar with closing theorems of the axioms of incidence and are able to design statistical tests by using the theory of finite geometries. They are able to construct orthogonal Latin squares and know the basic elements of the theory of block design.</td>
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<tr>
<td>Content</td>
<td>Finite geometries I, II: finite fields, rings of polynomials, finite affine planes, axioms of incidence, Euler's thirty-six officers problem, design of statistical tests, orthogonal Latin squares, transformation of finite planes, closing theorems of Desargues and Pappus-Pascal, hierarchy of closing theorems, finite coordinate planes, division rings, finite projective planes, duality principle, finite Möbius planes, error correcting codes, block design</td>
<td></td>
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<tr>
<td>Literature</td>
<td>- Max Jeger, Endliche Geometrien, ETH Skript 1988</td>
<td></td>
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<tr>
<td></td>
<td>- Albrecht Beutelspacher: Einführung in die endliche Geometrie I,II. Bibliographisches Institut 1983</td>
<td></td>
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<tr>
<td></td>
<td>- Margaret Lynn Batten: Combinatorics of Finite Geometries, Cambridge University Press</td>
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<tr>
<td></td>
<td>- Dambowski: Finite Geometries.</td>
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<tr>
<td></td>
<td>Does not take place this semester.</td>
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<<<< Selection: Analysis

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<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-4421-71L</td>
<td>Harmonic Analysis</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>A. Figalli</td>
</tr>
<tr>
<td>Abstract</td>
<td>The goal of this class is to give an introduction to harmonic analysis, covering a series of classical important results such as: 1) interpolation theorems 2) convergence properties of Fourier series 3) Calderón-Zygmund operators 4) Littlewood-Paley decomposition 5) Hardy and BMO spaces</td>
<td></td>
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<tr>
<td>Lecture notes</td>
<td>I plan to write some notes of the class.</td>
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<tr>
<td>Literature</td>
<td>There is no official textbook.</td>
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<tr>
<td>401-4475-71L</td>
<td>Microlocal Analysis</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>P. Hintz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Microlocal analysis is the analysis of partial differential equations in phase space. The first half of the course introduces basic notions such as pseudodifferential operators, wave front sets of distributions, and elliptic parametrices. The second half develops modern tools for the study of nonelliptic equations, with applications to wave equations arising in general relativity. Students will be able to analyze linear partial differential operators (with smooth coefficients) and their solutions in phase space, i.e. in the cotangent bundle. For various classes of operators including, but not limited to, elliptic and hyperbolic operators, they will be able to prove existence and uniqueness (possibly up to finite-dimensional obstructions) of solutions, and study the precise regularity properties of solutions. The first goal is to construct and apply parametrices (approximate inverses) or approximate solutions of PDEs using suitable calculi of pseudodifferential operators (ps.d.o.s). This requires defining ps.d.o.s and the associated symbol calculus on Euclidean space, proving the coordinate invariance of ps.d.o.s, and defining a ps.d.o. calculus on manifolds (including mapping properties on Sobolev spaces). The second goal is to analyze distributions and operations on them (such as: products, restrictions to submanifolds) using information about their wave front sets or other microlocal regularity information. Students will in particular be able to compute the wave front set of distributions. The third goal is to infer microlocal properties (in the sense of wave front sets) of solutions of general linear PDEs, with a focus on elliptic, hyperbolic and certain degenerate hyperbolic PDE. For hyperbolic operators, this includes proving the Duistermaat-Hörmander theorem on the propagation of singularities. For certain degenerate hyperbolic operators, students will apply positive commutator methods to probe results on the propagation of microlocal regularity at critical or invariant sets for the Hamiltonian vector field of the principal symbol of the partial differential operator under study.</td>
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</tbody>
</table>
Content

Tempered distributions, Sobolev spaces, Schwartz kernel theorem.

Symbols, asymptotic summation.

Pseudodifferential operators on Euclidean space: composition, principal symbols and the symbol calculus, elliptic parametrix construction, boundedness on Sobolev spaces.

Pseudodifferential operators on manifolds, elliptic operators on compact manifolds and Fredholm theory, basic symplectic geometry.

Microlocalization: wave front set, characteristic set; pairings, products, restrictions of distributions.

Hyperbolic evolution equations: existence and uniqueness of solutions, Egorov's theorem.

Propagation of singularities: the Duistermaat-Hörmander theorem, microlocal estimates at radial sets.

Applications to general relativity: asymptotic behavior of waves on de Sitter space.

Lecture notes

Lecture notes will be made available on the course website.

Literature

Lars Hörmander, "The Analysis of Linear Partial Differential Operators", Volumes I and III.

Alain Grigis and Johannes Sjöstrand, "Microlocal Analysis for differential operators: an introduction".

Prerequisites / notice

Students are expected to have a good understanding of functional analysis. Familiarity with distribution theory, the Fourier transform, and analysis on manifolds is useful but not strictly necessary; the relevant notions will be recalled in the course.

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies

Decision-making

Media and Digital Technologies

Problem-solving

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Leadership and Responsibility

Self-presentation and Social Influence

Sensitivity to Diversity

Domain D - Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

Selection: Further Realms

Number Title Type ECTS Hours Lecturers

401-3502-71L Reading Course

W 2 credits 4A Supervisors

401-3503-71L Reading Course

W 3 credits 6A Supervisors

401-3504-71L Reading Course

W 4 credits 9A Supervisors

401-3504-02L Reading Course (No. 2)

W 4 credits 9A Supervisors
Abstract

For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-0000-00L Communication in Mathematics

W 2 credits 1V

W. Merry

Abstract

Don’t hide your Next Great Theorem behind bad writing.

This course teaches fundamental communication skills in mathematics: how to write clearly and how to structure mathematical content for different audiences, from theses, to preprints, to personal statements in applications. In addition, the course will help you establish a working knowledge of LaTeX.

Objective

Knowing how to present written mathematics in a structured and clear manner.

Content

Topics covered include:

- Language conventions and common errors.
- How to write a thesis (more generally, a mathematics paper).
- How to use LaTeX.
- How to write a personal statement for Masters and PhD applications.

Lecture notes

Full lecture notes will be made available on my website:

https://www.merry.io/teaching/

Prerequisites / notice

There are no formal mathematical prerequisites.

Electives: Applied Mathematics and Further Application-Oriented Fields

Selection: Numerical Analysis

Number Title Type ECTS Hours Lecturers

401-4657-00L Numerical Analysis of Stochastic Ordinary Differential Equations

W 6 credits 3V+1U

A. Stein

Abstract

Course on numerical approximations of stochastic ordinary differential equations driven by Wiener processes. These equations have several applications, for example in financial option valuation. This course also contains an introduction to random number generation and Monte Carlo methods for random variables.

Objective

The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

Content

- Generation of random numbers
- Monte Carlo methods for the numerical integration of random variables
- Stochastic processes and Brownian motion
- Stochastic ordinary differential equations (SODEs)
- Numerical approximations of SODEs
- Applications to computational finance: Option valuation

Lecture notes

There will be English, typed lecture notes for registered participants in the course.

P. Glassermann:
Monte Carlo Methods in Financial Engineering.

P. E. Kloeden and E. Platen:
Numerical Solution of Stochastic Differential Equations.

Prerequisites / notice

Mandatory: Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.

a) mandatory courses:
Elementary Probability,
Probability Theory I.

b) recommended courses:
Stochastic Processes.


401-4785-00L Mathematical and Computational Methods in Photonics

W 8 credits 4G

H. Ammari

Abstract

The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces.
Objective
The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

The recent advances in nanoscience present great challenges for the applied and computational mathematics community. In nanophotonics, the aim is to control, manipulate, reshape, guide, and focus electromagnetic waves at nanometer length scales, beyond the resolution limit. In particular, one wants to break the resolution limit by reducing the focal spot and confine light to length scales that are significantly smaller than half the wavelength.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare. Light-based technologies can be used effectively for the very early detection of diseases, with non-invasive imaging techniques or point-of-care applications. They are also instrumental in the analysis of processes at the molecular level, giving a greater understanding of the origin of diseases, and hence allowing prevention along with new treatments. Photonic technologies also play a major role in addressing the needs of our ageing society: from pace-makers to synthetic bones, and from endoscopes to the micro-cameras used in in-vivo processes. Furthermore, photonics are also used in advanced lighting technology, and in improving energy efficiency and quality. By using photonic media to control waves across a wide band of wavelengths, we have an unprecedented ability to fabricate new materials with specific microstructures.

The main objective in this course is to report on the use of sophisticated mathematics in diffractive optics, plasmonics, super-resolution, photonic crystals, and metamaterials for electromagnetic invisibility and cloaking. The book merges highly nontrivial multi-mathematics in order to make a breakthrough in the field of mathematical modelling, imaging, and optimal design of optical nanodevices and nanostructures capable of light enhancement, and of the focusing and guiding of light at a subwavelength scale. We demonstrate the power of layer potential techniques in solving challenging problems in photonics, when they are combined with asymptotic analysis and the elegant theory of Gohberg and Sigal on meromorphic operator-valued functions.

In this course we shall consider both analytical and computational matters in photonics. The issues we consider lead to the investigation of fundamental problems in various branches of mathematics. These include asymptotic analysis, spectral analysis, mathematical imaging, optimal design, stochastic modelling, and analysis of wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

401-5003-71L At the Interface Between Semiclassical Analysis and Numerical Analysis of Wave-Scattering Problems
W 4 credits 2V E. Spence

Abstract
Postgraduate degree lecture

Content
Semiclassical analysis (SCA) is a branch of microlocal analysis concerned with rigorously analysing PDEs with large (or small) parameters. On the other hand, numerical analysis (NA) seeks to design numerical methods that are accurate, efficient, and robust, with theorems guaranteeing these properties. In the context of high-frequency wave scattering, both SCA and NA share the same goal — that of understanding the behaviour of the scattered wave — but these two fields have operated largely in isolation, mainly because the tools and techniques of the two fields are somewhat disjoint.

This by-and-large self-contained course focuses on the Helmholtz equation, which is arguably the simplest possible model of wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. This course will aim at being accessible both to students coming from a numerical-analysis/applied-maths background and to students coming from an analysis background.

Selection: Probability Theory, Statistics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-4607-67L</td>
<td>Schramm-Loewner Evolutions</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>W. Werner</td>
</tr>
<tr>
<td>401-3822-17L</td>
<td>Ising Model</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>V. Tassion</td>
</tr>
<tr>
<td>401-3628-14L</td>
<td>Bayesian Statistics</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>F. Sigrist</td>
</tr>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
</tbody>
</table>

401-4607-67L Schramm-Loewner Evolutions

Abstract
This advanced course will be an introduction to SLE (Schramm-Loewner Evolutions), which are a class of conformally invariant random curves in the plane. We will discuss their construction and some of their main properties.

Prerequisites / notice
Knowledge of Brownian motion and stochastic calculus and basic knowledge of complex analysis (Riemann's mapping theorem). Familiarity of lattice models such as percolation or the Ising model can be useful but not necessary.

401-3822-17L Ising Model

- Probability Theory,

Prerequisites / notice
Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

401-3628-14L Bayesian Statistics

Abstract
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayesian models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

Objective
Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content
Topics that we will discuss are:

- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

Lecture notes
A script will be available in English.

Literature

Additional references will be given in the course.

Prerequisites / notice
Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.
Time Series Analysis

The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear models. The course offers an introduction into analyzing time series, that is, observations which occur in time. The material will cover stationary processes, ARMA processes, spectral analysis, forecasting, nonstationary models, ARIMA models, and an introduction to GARCH models. The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.

| Objective | Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R. |
| Content | Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power. |
| Prerequisites / notice | The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held. |

<table>
<thead>
<tr>
<th>401-0649-00L</th>
<th>Applied Statistical Regression</th>
<th>W</th>
<th>5 credits</th>
<th>2V+1U</th>
<th>M. Dettling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning &quot;good practice&quot; that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.</td>
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<tr>
<td>Objective</td>
<td>The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.</td>
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<tr>
<td>Content</td>
<td>The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.</td>
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</tbody>
</table>

The third last of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

| Lecture notes | A script will be available. |
| Literature | Faraway (2005): Linear Models with R |
| Faraway (2006): Extending the Linear Model with R |
| Draper & Smith (1998): Applied Regression Analysis |
| Fox (2008): Applied Regression Analysis and GLMs |
| Montgomery et al. (2006): Introduction to Linear Regression Analysis |
| Taught competencies | Domain A - Subject-specific Competencies: Concepts and Theories | assessed |
| Techniques and Technologies | assessed |
| Domain B - Method-specific Competencies: Analytical Competencies | assessed |
| Decision-making | assessed |
| Media and Digital Technologies | assessed |
| Problem-solving | assessed |
| Project Management | not assessed |
| Domain C - Social Competencies: Communication | assessed |
| Cooperation and Teamwork | not assessed |
| Customer Orientation | not assessed |
| Leadership and Responsibility | not assessed |
| Self-presentation and Social Influence | not assessed |
| Sensitivity to Diversity | not assessed |
| Negotiation | not assessed |
| Domain D - Personal Competencies: Adaptability and Flexibility | assessed |
| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Integrity and Work Ethics | assessed |
| Self-awareness and Self-reflection | not assessed |
| Self-direction and Self-management | not assessed |

High-Dimensional Statistics

"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

| Objective | Knowledge of methods and basic theory for high-dimensional statistical inference |
| Content | Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and l1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling |
| Prerequisites / notice | Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics). |

Time Series Analysis

The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

| Objective | The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis. |
| Abstract | Does not take place this semester. |
| Content | The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies. |

| Lecture notes | A script will be available. |
| Literature | Faraway (2005): Linear Models with R |
| Faraway (2006): Extending the Linear Model with R |
| Montgomery et al. (2006): Introduction to Linear Regression Analysis |
| Taught competencies | Domain A - Subject-specific Competencies: Concepts and Theories | assessed |
| Techniques and Technologies | assessed |
| Domain B - Method-specific Competencies: Analytical Competencies | assessed |
| Decision-making | assessed |
| Media and Digital Technologies | assessed |
| Problem-solving | assessed |
| Project Management | not assessed |
| Domain C - Social Competencies: Communication | assessed |
| Cooperation and Teamwork | not assessed |
| Customer Orientation | not assessed |
| Leadership and Responsibility | not assessed |
| Self-presentation and Social Influence | not assessed |
| Sensitivity to Diversity | not assessed |
| Negotiation | not assessed |
| Domain D - Personal Competencies: Adaptability and Flexibility | assessed |
| Creative Thinking | assessed |
| Critical Thinking | assessed |
| Integrity and Work Ethics | assessed |
| Self-awareness and Self-reflection | not assessed |
| Self-direction and Self-management | not assessed |
Lecturers not assessed

M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics

Type

P. Glasserman, Monte Carlo Methods in Financial Engineering.

W

The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses

Concepts and Theories

Analytical Competencies

4V+1U

Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a

computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an

estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains
different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

Content

Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).

Generation of uniform random variables. Generation of random variables with arbitrary distributions (quantile transform, accept-reject,

importance sampling), simulation of Gaussian processes and diffusions. The precision of simulations, methods for variance reduction.

Introduction to Markov chains and Markov chain Monte Carlo (Metropolis-Hastings, Gibbs sampler, Hamiltonian Monte Carlo, reversible

jump MCMC).

Lecture notes

A script will be available in English.

Literature


Prerequisites / notice

Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central

limit theorem) will be assumed.

Selection: Financial and Insurance Mathematics

In the Master's programmes in Mathematics resp. Applied Mathematics 401-3913-01L Mathematical Foundations for Finance is eligible as an elective
course, but only if 401-3888-00L Introduction to Mathematical Finance isn't recognised for credits (neither in the Bachelor's nor in the Master's
programme). For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received
the credits.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3925-00L</td>
<td>Life Insurance Mathematics</td>
<td>W</td>
<td>4 credits</td>
<td>2V</td>
<td>M. Koller</td>
</tr>
</tbody>
</table>

The exams ONLY take place during the official ETH examination period.

Prerequisites:

- Knowledge of probability theory, statistics and applied stochastic processes.
- Domain A - Subject-specific Competencies:
  - Concepts and Theories
  - Techniques and Technologies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- Domain B - Method-specific Competencies
  - assessed
  - assessed
  - assessed
  - assessed
  - not assessed
  - assessed
  - not assessed

The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Type</th>
<th>Credits</th>
<th>V Semester</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3928-00L</td>
<td>Reinsurance Analytics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. Antal, P. Arbenz</td>
</tr>
</tbody>
</table>

**Abstract**
This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and models for extreme events such as natural or man-made catastrophes. The lecture covers reinsurance contracts, Experience and Exposure pricing, natural catastrophe modelling, solvency regulation, and insurance linked securities.

**Objective**
This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

**Topics covered include:**
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

**Content**
This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

**Topics covered include:**
- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models.
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks.
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context.
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2.
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds.

**Lecture notes**
Slides and lecture notes will be made available.

**Prerequisites / notice**
Basic knowledge in statistics, probability theory, and actuarial techniques.

---

**401-3927-00L Mathematical Modelling in Life Insurance**

**Abstract**
In life insurance, it is essential to have adequate mortality tables, be it for reserving or pricing purposes. The course provides the tools necessary to create mortality tables from scratch. Additionally, we study various guarantees embedded in life insurance products and learn to price them with the help of stochastic models.

**Objective**
The course's objective is to provide the students with the understanding and the tools to create mortality tables on their own. Additionally, students should learn to price embedded options in life insurance. Aside of the mere application of specific models, they should develop an intuition for the various drivers of the value of these options.

**Content**
Following main topics are covered:

1. Guarantees and options embedded in life insurance products.
   - Stochastic valuation of participating contracts
   - Stochastic valuation of Unit Linked contracts
2. Mortality Tables:
   - Determining raw mortality rates
   - Smoothing techniques: Whittaker-Henderson, smoothing splines,...
   - Trends in mortality rates
   - Stochastic mortality model due to Lee and Carter
   - Neural Network extension of the Lee-Carter model
   - Integration of safety margins

**Lecture notes**
Lectures notes and slides will be provided.
The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.

### Selection: Mathematical Physics, Theoretical Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>G. M. Graf</td>
</tr>
<tr>
<td></td>
<td>Special Students UZH must book the module PHY551 directly at UZH.</td>
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<tr>
<td>Abstract</td>
<td>This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity. Topics include: - Relativistic quantum mechanics - Quantisation of bosonic and fermionic fields - Interactions in perturbation theory - Scattering processes and decays - Elementary processes in QED - Radiative corrections</td>
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<tr>
<td>Objective</td>
<td>The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.</td>
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<tr>
<td>Lecture notes</td>
<td>Will be provided as the course progresses</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
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<tr>
<td></td>
<td>Concepts and Theories</td>
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<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<td>Project Management</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
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<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0861-00L</td>
<td>Statistical Physics</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>M. Sigrist</td>
</tr>
<tr>
<td>Abstract</td>
<td>This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.</td>
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<tr>
<td>Objective</td>
<td>This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics education.</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture notes available in English.</td>
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<tr>
<td>Literature</td>
<td>No specific book is used for the course. Relevant literature will be given in the course.</td>
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0830-00L</td>
<td>General Relativity</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>C. Anastasiou</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.</td>
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<tr>
<td>Objective</td>
<td>Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).</td>
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<tr>
<td>Content</td>
<td>Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.</td>
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</tbody>
</table>
The lectures will cover a range of topics, tentatively including the following:
- Graph sparsifications while preserving cuts or distances
- Various combinatorial and algorithmic techniques

Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to combinatorial algorithms, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**
- The students will get an overview of various combinatorial methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**
- Mechanics of point particles and extended objects
- String modes and their quantisation; higher dimensions, supersymmetry
- D-branes, T-duality
- Supergravity as a low-energy effective theory, strings on curved backgrounds
- Two-dimensional field theories (classical/quantum, conformal/non-conformal)

**Literature**

**Prerequisites / notice**
Recommended: Quantum Field Theory I (in parallel)

### Selection: Mathematical Optimization, Discrete Mathematics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3055-64L</td>
<td>Algebraic Methods in Combinatorics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>B. Sudakov</td>
</tr>
</tbody>
</table>

**Abstract**
Combinatorics is a fundamental mathematical discipline as well as an essential component of many mathematical areas, and its study has experienced an impressive growth in recent years. This course provides a gentle introduction to combinatorial methods, illustrated by examples and focusing on basic ideas and connections to other areas.

**Objective**
- The students will get an overview of various combinatorial methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**
- Mechanics of point particles and extended objects
- String modes and their quantisation; higher dimensions, supersymmetry
- D-branes, T-duality
- Supergravity as a low-energy effective theory, strings on curved backgrounds
- Two-dimensional field theories (classical/quantum, conformal/non-conformal)

**Literature**

**Prerequisites / notice**
Recommended: Quantum Field Theory I (in parallel)

### Auswahl: Theoretical Computer Science, Discrete Mathematics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-4500-00L</td>
<td>Advanced Algorithms</td>
<td>W</td>
<td>9 credits</td>
<td>3V+2U+3A</td>
<td>M. Ghaffari, G. Zuzic</td>
</tr>
</tbody>
</table>

**Abstract**
This is a graduate-level course on algorithm design (and analysis). It covers a range of topics and techniques in approximation algorithms, sketching and streaming algorithms, and online algorithms.

**Objective**
- The students will get an overview of various combinatorial methods for solving combinatorial problems. We expect them to understand the proof techniques and to use them autonomously on related problems.

**Content**
- The lectures will cover a range of topics, tentatively including the following: graph sparsifications while preserving cuts or distances, various approximation algorithms techniques and concepts, metric embeddings and probabilistic tree embeddings, online algorithms, multiplicative weight updates, sketching algorithms, data structures, and derandomization.

**Lecture notes**
https://people.inf.ethz.ch/gmohsen/AA21/

**Prerequisites / notice**
This course is designed for masters and doctoral students and it especially targets those interested in theoretical computer science, but it should also be accessible to last-year bachelor students.

Sufficient comfort with both (A) Algorithm Design & Analysis and (B) Probability & Concentrations. E.g., having passed the course Algorithms, Probability, and Computing (APC) is highly recommended, though not required formally. If you are not sure whether you’re ready for this class or not, please consult the instructor.

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-1425-00L</td>
<td>Geometry: Combinatorics and Algorithms</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>B. Gärtner, E. Welzl, M. Hoffmann, M. Wettstein</td>
</tr>
</tbody>
</table>

**Abstract**
Geometric structures are useful in many areas, and there is a need to understand their structural properties, and to work with them algorithmically. The lecture addresses theoretical foundations concerning geometric structures. Central objects of interest are triangulations. We study combinatorial (Does a certain object exist?) and algorithmic (Questions: Can we find a certain object efficiently?)

**Objective**
- The goal is to make students familiar with fundamental concepts, techniques and results in combinatorial and computational geometry, so as to enable them to model, analyze, and solve theoretical and practical problems in the area and in various application domains.
- In particular, we want to prepare students for conducting independent research, for instance, within the scope of a thesis project.
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

Prerequisites / notice: Prerequisites: The course assumes basic knowledge of discrete mathematics and algorithms, as supplied in the first semesters of Bachelor Studies at ETH. After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.

### Reading Course

To start an individual reading course, contact an authorised supervisor.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-4944-20L</td>
<td>Mathematics of Data Science</td>
<td>W</td>
<td>8 credits</td>
<td>4G</td>
<td>A. Bandeira</td>
</tr>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
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<tr>
<td>401-3502-71L</td>
<td>Reading Course</td>
<td>W</td>
<td>2 credits</td>
<td>4A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei.
Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3503-71L Reading Course
To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/math/department/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf
and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-71L Reading Course
To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/math/department/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf
and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-3504-02L Reading Course (No. 2)
To start an individual reading course, contact an authorised supervisor
https://www.ethz.ch/content/dam/ethz/special-interest/math/department/Intranet/Students/Study_Administration/Theses_Reading_Courses/berechtigungsliste.pdf
and register your reading course in myStudies.

Abstract
For this Reading Course proactive students make an individual agreement with a lecturer to acquire knowledge through independent literature study.

401-0000-00L Communication in Mathematics
Does not take place this semester.

Abstract
Don't hide your Next Great Theorem behind bad writing.

This course teaches fundamental communication skills in mathematics: how to write clearly and how to structure mathematical content for different audiences, from theses, to preprints, to personal statements in applications. In addition, the course will help you establish a working knowledge of LaTeX.

Objective
Knowing how to present written mathematics in a structured and clear manner.

Content
Topics covered include:
- Language conventions and common errors.
- How to write a thesis (more generally, a mathematics paper).
- How to use LaTeX.
- How to write a personal statement for Masters and PhD applications.

Lecture notes
Full lecture notes will be made available on my website:
https://www.merry.io/teaching/

Prerequisites / notice
There are no formal mathematical prerequisites.

Electives (direction Applied Mathematics MSc only)

Electives from applied mathematics and further application-oriented fields that are only eligible for credits for the Master's degree in Applied Mathematics.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0532-00L</td>
<td>Nonlinear Dynamics and Chaos I</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>G. Haller</td>
</tr>
</tbody>
</table>

Abstract
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

Content
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.
### Application Area

Only necessary and eligible for the Master degree in Applied Mathematics. One of the application areas specified must be selected for the category Application Area for the Master degree in Applied Mathematics. At least 8 credits are required in the chosen application area.

#### Atmospheric Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1221-00L</td>
<td>Dynamics of Large-Scale Atmospheric Flow</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>H. Wernli, L. Papritz</td>
</tr>
</tbody>
</table>

**Abstract**

This lecture course is the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

**Objective**

Understanding the dynamics of large-scale atmospheric flow

**Content**

Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

**Lecture notes**

Dynamics of large-scale atmospheric flow

**Literature**

- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

**Prerequisites / notice**

Physics I, II, Environmental Fluid Dynamics

#### Biology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0017-00L</td>
<td>Computational Biology</td>
<td>W</td>
<td>6</td>
<td>3G+2A</td>
<td>T. Vaughan</td>
</tr>
</tbody>
</table>

**Abstract**

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

**Objective**

Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
  - phylogenetic & phylodynamic inference
  - maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

**Content**

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GNAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phyloodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

**Lecture notes**

Lecture slides will be available on moodle.

**Literature**

- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

**Prerequisites / notice**

Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the Zurich-based students, we highly recommend the voluntary course "Introduction to Programming", which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.cbb.ethz.ch/news-events.html

For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d or working through the script provided as part of this R course.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>636-0007-00L</td>
<td>Computational Systems Biology</td>
<td>W</td>
<td>6</td>
<td>3V+2U</td>
<td>J. Stelling</td>
</tr>
</tbody>
</table>

**Abstract**

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

**Objective**

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

**Content**

Biological networks need new computational tools. The main concepts introduced are:

- Systems Biology, focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on selected algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.
**Introduction to Dynamic Programming and Optimal Control.**

Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. The goal of this course is to understand and appreciate mathematical models and computational methods that provide insight into the evolution of processes in general and in particular. Students should analyze and evaluate models and their application critically and be able to design new models.

**Evolutionary Dynamics**

Evolution is the one theory that encompasses all of biology. It provides a single, unifying concept to understand the living systems that we observe today. We will introduce several types of mathematical models of evolution to describe gene frequency changes over time in the context of different biological systems, focusing on asexual populations. Viruses and cancer cells provide the most prominent examples of such systems and they are at the same time of great biomedical interest. The course will cover some classical mathematical population genetics and population dynamics, and also introduce several new approaches. This is reflected in a diverse set of mathematical concepts which make their appearance throughout the course, all of which are introduced from scratch. Topics covered include the quasispecies equation, evolution of HIV, evolutionary game theory, evolutionary graph theory, tumor evolution, stochastic tunneling, genetic progression of cancer, diffusion theory, fitness landscapes, branching processes, and evolutionary escape.

**Dynamic Programming and Optimal Control**

Cover the fundamental concepts of Dynamic Programming & Optimal Control.

**Method-specific Competencies**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Analytical Competencies
  - Problem-solving
  - Communication
  - Cooperation and Teamwork
  - Critical Thinking
  - Self-direction and Self-management

**Literature**


**Prerequisites / notice**

- Prerequisites: Basic mathematics (linear algebra, calculus, probability)

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**Control and Automation**

### Number Title

**151-0563-01L Dynamic Programming and Optimal Control**

**Objective**

- Introduction to Dynamic Programming and Optimal Control.
- Covers the fundamental concepts of Dynamic Programming & Optimal Control.
- Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Content**

- Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**


**Prerequisites / notice**

- Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

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**Economics**

### Number Title

**401-3929-00L Financial Risk Management in Social and Pension Insurance**

**Abstract**

- Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability.
- We study short-term and long-term financial risk and its interplay with other risk factors, and we develop methods for the measurement and management of financial risk and return in an asset/liability context with the goal of assuring sustainable funding.

**Objective**

- Understand the basic asset-liability framework: essential principles and properties of social and pension insurance: cash flow matching, duration matching, valuation portfolio and loose coupling; the notion of financial risk; long-term vs. short-term risk; coherent measures of risk.
- Understand the conditions for sustainable funding: derivation of required returns; interplay between return levels, contribution levels and other parameters; influence of guaranteed benefits.
- Understand the notion of risk-taking capability: capital process as a random walk; measures of long-term risk and relation to capital; short-term solvency vs. long-term stability; effect of embedded options and guarantees; interplay between required return and risk-taking capability.
- Be able to study empirical properties of financial assets: the Normal hypothesis and the deviations from it; statistical tools for investigating relevant risk and return properties of financial assets; time aggregation properties; be able to conduct analysis of real data for the most important asset classes.
- Understand and be able to carry out portfolio construction: the concept of diversification; limitations to diversification; correlation breakdown; incorporation of constraints; sensitivities and shortcomings of optimized portfolios.
- Understand and interpret the asset-liability interplay: the optimized portfolio in the asset-liability framework; short-term risk vs. long-term risk; the influence of constraints; feasible and non-feasible solutions; practical considerations.
- Understand and be able to address essential problems in asset / liability management, e.g. optimal risk / return positioning, optimal discount rate, target value for funding ratio or turnaround issues.
- Have an overall view: see the big picture of what asset returns can and cannot contribute to social security; be aware of the most relevant outcomes; know the role of the actuary in the financial risk management process.

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**Data:** 14.12.2021 12:41  **Autumn Semester 2021**  **Page 1613 of 2152**
Content
For pension insurance and other forms of social insurance, investment returns are an important source of funding. In order to earn these returns, substantial financial risks must be taken, and these risks represent an important threat to financial stability, in the long term and in the short term.

Risk and return of financial assets cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

Lecture notes
Extensive handouts will be provided. Moreover, practical examples and data sets in Excel and R will be made available.

Prerequisites / notice
Solid base knowledge of probability and statistics is indispensable. Specialized concepts from financial and insurance mathematics as well as quantitative risk management will be introduced in the lecture as needed, but some prior knowledge in some of these areas would be an advantage.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.

### 363-0537-00L Resource and Environmental Economics

**Objective**
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

**Content**
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

**Literature**

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### 363-0503-00L Principles of Microeconomics

**Abstract**
The course introduces basic principles, problems and approaches of microeconomics. This provides the students with reflective and contextual knowledge on how societies use scarce resources to produce goods and services and ensure a (fair) distribution.

**Objective**
The learning objectives of the course are:

1. Students must be able to discuss basic principles, problems and approaches in microeconomics.
2. Students can analyse and explain simple economic principles in a market using supply and demand graphs.
3. Students can contrast different market structures and describe firm and consumer behaviour.
4. Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole.
5. Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics.
6. Students can apply simple mathematical concepts on economic problems.

**Prerequisites / notice**
This course is for MSc students only. BSc students register for 363-1109-00L "Einführung in die Mikroökonomie".

**Literature**
Content
The resources on our planet are finite. The discipline of microeconomics therefore deals with the question of how society can use scarce resources to produce goods and services and ensure a (fair) distribution. In particular, microeconomics deals with the behaviour of consumers and firms in different market forms. Economic considerations and discussions are not part of classical engineering and science study programme. Thus, the goal of the lecture "Principles of Microeconomics" is to teach students how economic thinking and argumentation works. The course should help the students to look at the contents of their own studies from a different perspective and to be able to critically reflect on economic problems discussed in the society.

Topics covered by the course are:
- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade

Lecture notes
Lecture notes, exercises and reference material can be downloaded from Moodle.

Literature

For students taking only the course "Principles of Microeconomics" there is a shorter version of the same book:

Complementary:

Prerequisites / notice
GESS (Science in Perspective): This lecture is for MSc students only. BSc students register for 363-1109-00L Einführung in die Mikroökonomie.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
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</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
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<tr>
<td></td>
<td>Customer Orientation</td>
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<tr>
<td></td>
<td>Leadership and Responsibility</td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
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<td></td>
<td>Sensitivity to Diversity</td>
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<tr>
<td></td>
<td>Negotiation</td>
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</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

363-0565-00L Principles of Macroeconomics

Abstract
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

Objective
This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems.

Content
This course helps you understand the world in which you live. There are many questions about the macroeconomy that might spark your curiosity. Why are living standards so meagre in many African countries? Why do some countries have high rates of inflation while others have stable prices? Why have some European countries adopted a common currency? These are just a few of the questions that this course will help you answer. Furthermore, this course will give you a better understanding of the potential and limits of economic policy. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

Lecture notes
The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15062) contains announcements, course information and lecture slides.

Literature

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.
The main aim of this course is to analyse the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy and the differences between monetary policy rules and discretionary policy. It will also make connections between theoretical economic concepts and current real world issues.

Objective

This lecture will introduce the fundamentals of monetary economics and explain the working and impact of monetary policy. The main aim of this course is to describe and analyze the goals of monetary policy and to review the instruments available to central banks in order to pursue these goals. It will focus on the transmission mechanisms of monetary policy, the effectiveness of monetary policy actions, the differences between monetary policy rules and discretionary policy, as well as in institutional issues concerning central banks, transparency of monetary authorities and monetary policy in a monetary union framework. Moreover, we discuss the implementation of monetary policy in practice and the design of optimal policy.

Content

For the functioning of today's economy, central banks and their policies play an important role. Monetary policy is the policy adopted by the monetary authority of a country, the central bank. The central bank controls either the interest rate payable on very short-term borrowing or the money supply, often targeting inflation or the interest rate to ensure price stability and general trust in the currency. This monetary policy course looks into today's major questions related to policies of central banks. It provides insights into the monetary policy process using core economic principles and real-world examples.

Lecture notes

The course webpage (to be found at https://moodle-app2.let.ethz.ch/course/view.php?id=15063) contains announcements, course information and lecture slides.

Literature

The course will be based on chapters of:


Basic knowledge in international economics and a good background in macroeconomics.

Number Title Type ECTS Hours Lecturers

<table>
<thead>
<tr>
<th>Finance</th>
</tr>
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<tbody>
<tr>
<td>Number Title Type ECTS Hours Lecturers</td>
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</tbody>
</table>

401-8905-00L Financial Engineering (University of Zurich) W 6 credits 4G University lecturers

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: MFOEC200

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

This lecture is intended for students who would like to learn more on equity derivatives modelling and pricing.

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The course will cover the following topics:

- Light and perception
- Digital image formation
- Image enhancement and feature extraction
- Unitary transformations
- Color and texture
- Image segmentation
- Motion extraction and tracking
- 3D data extraction
- Invariant features
- Specific object recognition and object class recognition
- Deep learning and AI-based approaches to image analysis

The course will turn to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets will be discussed.

The course language is English.

Prerequisites:
- Basic concepts of mathematical analysis and linear algebra.
- Basic knowledge of probability theory and stochastic calculus.
- Basic knowledge of mathematical finance including no-arbitrage, portfolio replication and risk-neutral measure, and Black-Scholes model, stochastic and jump-diffusion models, and highlight their assumptions and limitations.

Course material:
- Script.
- Computer demonstrations.
- Exercises and problem solutions.

Lecture notes:
- University lecturers.

Prerequisites / notice:
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

Abstract:
- This course develops and refines tools for evaluating investments (capital budgeting), capital structure, and corporate securities. The course seeks to deepen students' understanding of the link between corporate finance theory and practice.

Objective:
- This course develops and refines tools for evaluating investments (capital budgeting), capital structure, and corporate securities. With respect to capital structure, the course will start with the famous Miller and Modigliani irrelevance proposition and then move on to study the effects of taxes, bankruptcy costs, information asymmetries between firms and the capital markets, and agency costs. In this context, we will also study how leverage affects some central financial ratios that are often used in practice to assess firms and their stock. Other topics include corporate cash holdings, the use and pricing of convertible bonds, and risk management. The latter two topics involve option pricing. With respect to capital budgeting, the course pays special attention to tax effects in valuation, including in the estimation of the cost of capital. We will also study payout policy (dividends and share repurchases), The course seeks to deepen students' understanding of the link between corporate finance theory and practice. Various cases will be assigned to help reach this objective.

Content:
- Topics Covered:
  1. Capital structure: Perfect markets and irrelevance
  2. Risk, leverage, taxes, and the cost of capital
  3. Leverage and financial ratios
  4. Payout policy: Dividends and share repurchases
  5. Capital structure: Taxes and bankruptcy costs
  6. Capital structure: Information asymmetries, agency costs, cash holdings
  7. Valuation: DCF, adjusted present value and WACC
  8. Valuation using options
  9. The use and pricing of convertible bonds
  10. Corporate risk management

Prerequisites / notice:
- This course replaces "Advanced Corporate Finance I" (MOEC0288), which will be discontinued from HS16.

Image Processing and Computer Vision

Number Title Type ECTS Hours Lecturers
---
227-0447-00L Image Analysis and Computer Vision W 6 credits 3V+1U L. Van Gool, E. Konukoglu, F. Yu

Abstract:

Objective:
- Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

Content:
- This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning. The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer. The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Lecture notes:
- Course material Script, computer demonstrations, exercises and problem solutions.

Prerequisites / notice:
- Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.


### Information and Communication Technology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0105-00L</td>
<td>Introduction to Estimation and Machine Learning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>H.-A. Loeliger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Mathematical basics of estimation and machine learning, with a view towards applications in signal processing.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>Students master the basic mathematical concepts and algorithms of estimation and machine learning.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Review of probability theory; basics of statistical estimation; linear algebra; Hilbert spaces; Gaussian random variables; singular-value decomposition; kernel methods, neural networks, and more</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes will be handed out as the course progresses.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Solid basics in linear algebra and probability theory</td>
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| 227-0101-00L | Discrete-Time and Statistical Signal Processing | W    | 6    | 4G    | H.-A. Loeliger      |
| **Abstract** | The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm. |
| **Objective** | The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurrent theme throughout the course is the stable and robust "inversion" of a linear filter. |
| **Content**  | 1. Discrete-time linear systems and filters; state-space realizations, z-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion. |
| **Lecture notes** | Lecture Notes |
| **Prerequisites / notice** | Solid basics in linear algebra and probability theory |

| 227-0417-00L | Information Theory I | W    | 6    | 4G    | A. Lapidoth |
| **Abstract** | This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity. |
| **Objective** | The fundamentals of Information Theory including Shannon's source coding and channel coding theorems |
| **Content**  | 1. The entropy rate of a source. Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity |
| **Literature** | T.M. Cover and J. Thomas, Elements of Information Theory (second edition) |

### Machine Learning

The list is not yet complete.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-5210-00L</td>
<td>Probabilistic Artificial Intelligence</td>
<td>W</td>
<td>8</td>
<td>3V+2U+2A</td>
<td>A. Krause</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit &quot;intelligent&quot; behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Topics covered: - Probability - Probabilistic inference (variational inference, MCMC) - Bayesian learning (Gaussian processes, Bayesian deep learning) - Probabilistic planning (MDPs, POMDPs) - Multi-armed bandits and Bayesian optimization - Reinforcement learning</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Solid basic knowledge in statistics, algorithms and programming. The material covered in the course &quot;Introduction to Machine Learning&quot; is considered as a prerequisite.</td>
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</table>

| 263-3210-00L | Deep Learning                                   | W    | 8    | 3V+2U+2A | F. Perez Cruz, A. Lucchi |
| **Abstract** | Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations. |
| **Objective** | In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology. |

Prerequisites / notice

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  Advanced Machine Learning
  https://ml2.inf.ethz.ch/courses/aml/

  Computational Intelligence Lab
  http://da.inf.ethz.ch/teaching/2019/CIL/

  Introduction to Machine Learning
  https://las.inf.ethz.ch/teaching/introml-S19

  Statistical Learning Theory
  http://ml2.inf.ethz.ch/courses/slt/

  Computational Statistics
  https://stat.ethz.ch/lectures/s19/comp-stats.php

  Probabilistic Artificial Intelligence
  https://las.inf.ethz.ch/teaching/pai-f18

252-3005-00L Natural Language Processing W 5 credits 2V+2U+1A R. Cotterell
Number of participants limited to 400.

Abstract
This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Objective
The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

Content
This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Literature
Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

263-5255-00L Foundations of Reinforcement Learning W 5 credits 2V+2A N. He
Number of participants limited to 190.

Abstract
Reinforcement learning (RL) has been in the limelight of many recent breakthroughs in artificial intelligence. This course focuses on theoretical and algorithmic foundations of reinforcement learning, through the lens of optimization, modern approximation, and learning theory. The course targets M.S. students with strong research interests in reinforcement learning, optimization, and control.

Objective
This course aims to provide students with an advanced introduction of RL theory and algorithms as well as bring them near the frontier of this active research field.

By the end of the course, students will be able to
- Identify the strengths and limitations of various reinforcement learning algorithms;
- Formulate and solve sequential decision-making problems by applying relevant reinforcement learning tools;
- Generalize or discover “new” applications, algorithms, or theories of reinforcement learning towards conducting independent research on the topic.

Content
Basic topics include fundamentals of Markov decision processes, approximate dynamic programming, linear programming and primal-dual perspectives of RL, model-based and model-free RL, policy gradient and actor-critic algorithms, Markov games and multi-agent RL. If time allows, we will also discuss advanced topics such as batch RL, inverse RL, causal RL, etc. The course keeps strong emphasis on in-depth understanding of the mathematical modeling and theoretical properties of RL algorithms.

Lecture notes
Lecture notes will be posted on Moodle.

Literature
Algorithms for Reinforcement Learning, Csaba Czepesvári.

Prerequisites / notice
Students are expected to have strong mathematical background in linear algebra, probability theory, optimization, and machine learning.

Material Modelling and Simulation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>327-1201-00L</td>
<td>Transport Phenomena I</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>J. Vermant</td>
</tr>
</tbody>
</table>

Abstract
Phenomenological approach to "Transport Phenomena" based on balance equations supplemented by thermodynamic considerations to formulate the undetermined fluxes in the local species mass, momentum, and energy balance equations; Solutions of a few selected problems relevant to materials science and engineering both analytically and using numerical methods.

Objective
The teaching goals of this course are on five different levels:
1. Deep understanding of fundamentals: local balance equations, constitutive equations for fluxes, entropy balance, interfaces, idea of dimensionless numbers and scaling, ...
2. Ability to use the fundamental concepts in applications
3. Insight into the role of boundary conditions (mainly part 2)
4. Knowledge of a number of applications.
5. Flavor of numerical techniques: finite elements and finite differences.
Quantum Chemistry

Number | Title                     | Type | ECTS | Hours | Lecturers
--- | --------------------------|------|------|-------|------------------
529-0003-01L | Advanced Quantum Chemistry | W   | 6    | 3G    | M. Reiher, A. Baiardi

Abstract
Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer.

Examples are:
- Operators derived from principles of relativistic quantum mechanics
- Relativistic effects + methods of relativistic quantum chemistry
- Open-shell molecules + spin-density functional theory
- New electron-correlation theories

Objective
The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood. Examples are the Born-Oppenheimer approximation and the expansion of the wave function in a set of pre-defined basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.

Content
1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein’s special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon and Dirac equation; the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group
9) Quantum chemistry without the Born-Oppenheimer approximation

Lecture notes
A set of detailed lecture notes will be provided, which will cover the whole course.

Simulation of Semiconductor Devices

"Simulation of Semiconductor Devices" is no longer offered as an application area.

Systems Design

Number | Title                     | Type | ECTS | Hours | Lecturers
--- | --------------------------|------|------|-------|------------------
363-0541-00L | Systems Dynamics and Complexity | W   | 3    | 3G    | F. Schweitzer
Abstract
Finding solutions: what is complexity, problem solving cycle.
Implementing solutions: project management, critical path method, quality control feedback loop.
Controlling solutions: Vensim software, feedback cycles, control parameters, instabilities, chaos, oscillations and cycles, supply and demand, production functions, investment and consumption.

Objective
A successful participant of the course is able to:
- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches.
- apply the problem solving cycle as a systematic approach to identify problems and their solutions.
- calculate project schedules according to the critical path method.
- setup and run systems dynamics models by means of the Vensim software.
- identify feedback cycles and reasons for unintended systems behavior.
- analyze the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics.

Content
Why are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical systems dynamics, nonlinear dynamics and macroeconomic modeling.
The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts.

These are provided as home work and two of these will be graded (see "Prerequisites").

Lecture notes
The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture.

Theoretical Physics

In the Master's programme in Applied Mathematics 402-0205-00L Quantum Mechanics I is eligible as a course unit in the application area Theoretical Physics, but only if 402-0224-00L Theoretical Physics wasn't or isn't recognised for credits (neither in the Bachelor's nor in the Master's programme).
For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

402-0809-00L
Introduction to Computational Physics

402-2203-01L
Classical Mechanics

402-0861-00L
Statistical Physics

Number Title Type ECTS Hours Lecturers

402-0809-00L Introduction to Computational Physics W 8 credits 2V+2U A. Adelmann

402-2203-01L Classical Mechanics W 7 credits 4V+2U R. Renner

402-0861-00L Statistical Physics W 10 credits 4V+2U M. Sigrist

For the category assignment take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

Number Title Type ECTS Hours Lecturers

Autumn Semester 2021
Page 1621 of 2152
Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions.
Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems.
Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons.
Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state phonons, in elastic media and melting.
One-dimensional interacting systems.
Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order.

Quantum Field Theory I
101-0417-00L

**Content**

- Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations of the theory as well as the underlying physical principles and concepts. It covers selected applications, such as the Schwarzschild solution and gravitational waves.
- Some of the phenomena it predicts (with a focus on black holes).
- Basic understanding of general relativity, its mathematical foundations (in particular the relevant aspects of differential geometry), and some of the phenomena it predicts (with a focus on black holes).
- Introduction to the theory of general relativity. The course puts a strong focus on the mathematical foundations, such as differentiable manifolds, the Riemannian and Lorentzian metric, connections, and curvature. It discusses the underlying physical principles, e.g., the equivalence principle, and concepts, such as curved spacetime and the energy-momentum tensor. The course covers some basic applications and special cases, including the Newtonian limit, post-Newtonian expansions, the Schwarzschild solution, light deflection, and gravitational waves.

**Literature**

- C. Misner, K. Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- C. Misner, K, Thorne and J. Wheeler: Gravitation
- S. Carroll - Spacetime and Geometry: An Introduction to General Relativity
- R. Wald - General Relativity
- S. Weinberg - Gravitation and Cosmology

**Electives Theoretical Physics**

**Transportation Science**

**Number**

- 101-0417-00L

**Title**

- Transport Planning Methods

**Type**

- W

**ECTS**

- 6

**Hours**

- 4G

**Lecturers**

- C. Anastasiou

**Abstract**

- The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

**Objective**

- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool
This seminar provides a glimpse of two sister geometries that have recently earned a central role in mathematics interacting with other areas. By giving half-hour talks about each geometry, typing short notes for those talks and participating in talks by others, each participant will gain a deeper understanding of these geometries.

**Student Seminar in Symplectic vs. Contact Geometry**

**P. Biran**

A list of references and further information will be given in the beginning of September.

**Student Seminar in Algebraic Geometry: Complex Algebraic Surfaces**

**B. Acu Bulut**


**Seminars and Seminar Papers**

**NOTICE:** The number of seminar places is limited, and the special selection procedure should help to allocate the places not primarily according to the registration time. Everybody is waitlisted first when he/she tries to register for a seminar in myStudies. Moreover: Only one mathematics seminar can be chosen per semester. In case you need to attend 2 seminars in this semester, please take contact with the Study Administration (email: studiensekretariat@math.ethz.ch).

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
401-3100-71L | Student Seminar in Number Theory: L-Functions | W | 4 credits | 2S | M. Schwagenscheidt
**Number of participants limited to 24.**

**Abstract**

Seminar on the basic theory of Dirichlet L-functions and some applications in number theory.

**Objective**

In the seminar we will study Dirichlet L-functions, which generalize the classical Riemann zeta function. We discuss their basic properties, such as the analytic continuation and the functional equation, and the rationality of some of their special values. Moreover, we investigate the connection of Dirichlet L-functions with the Dedekind zeta functions of quadratic number fields. As main applications, we prove Dirichlet's class number formula for quadratic fields and Dirichlet's Theorem on arithmetic progressions.

We follow the book of Don Zagier "Zetafunktionen und quadratische Körper”.

**Content**

Please see the website of the seminar for a list of topics: [https://people.math.ethz.ch/~mschwagen/lfunctions](https://people.math.ethz.ch/~mschwagen/lfunctions)

**Literature**

 Apostol - Introduction to analytic number theory
Davenport - Multiplicative number theory
Serre - A course in arithmetic
Zagier - Zetafunktionen und quadratische Körper

**Prerequisites / notice**

Some familiarity with the basic notions of algebra (groups, rings, fields), complex analysis (holomorphic/meromorphic functions, the residue theorem) and elementary number theory (congruences, Legendre symbol, quadratic reciprocity) will be helpful.

**401-3140-71L**

Student Seminar in Algebraic Geometry: Complex Algebraic Surfaces

**Number of participants limited to 12.**

**Abstract**

The aim of the seminar is to understand the Enriques classification of complex algebraic surfaces.

**Objective**

We will see how techniques of algebraic geometry are applied to classify complex algebraic surfaces. Along the way we discuss invariants from cohomology and intersection theory and encounter important examples of varieties, such as ruled, abelian and K3 surfaces.

**Prerequisites / notice**

We assume familiarity with the basic concepts of Algebraic Geometry, roughly in the amount of chapters II and III of Hartshorne’s book.

**401-3050-71L**

Student Seminar in Combinatorics

**Number of participants limited to 12.**

**Abstract**

Quasimorphisms and Symplectic Geometry

**Number of participants limited to 12.**

**Objective**

In this seminar we will define quasimorphisms and use them as an algebraic tool to study various automorphism groups of manifolds. After a short introduction to symplectic geometry, we will mainly focus on the group of Hamiltonian diffeomorphisms and the Calabi quasimorphism.

**Objective**

By giving two half-hour talks, typing short summaries for those talks and participating in talks by others, each participant will gain familiar with the concept of quasimorphisms, learn about some concrete examples in and outside the world of symplectic geometry, as well as develop presentation and collaboration skills.

**Literature**

A list of references and further information will be given in the beginning of September.

**Prerequisites / notice**

Prerequisites: knowledge of Differential Geometry I and Algebraic Topology I.

**401-4530-71L**

Knots andlinks in 3-manifolds

**Number of participants limited to 12.**

**Abstract**

This seminar provides a glimpse of two sister geometries that have recently earned a central role in mathematics interacting with other areas.

Side by side, we will discuss basics of symplectic and contact manifolds, some key submanifolds (lagrangian and legendarian) and the toric subclasses (symplectic and contact), which have gained prominence as testing grounds for other theories.

**Objective**

By giving half-hour talks about each geometry, typing short notes for those talks and participating in talks by others, each participant will have the opportunity to get acquainted with the landscape of symplectic and contact worlds, expand their command of geometry and topology, and develop presentation and collaboration skills.

**Literature**

The Seminar webpage (under learning materials) contains a list of references and further information.

**Prerequisites / notice**

Prior knowledge of differential geometry and algebraic topology is required. Details of the seminar organization will be discussed in the first meeting.
401-3940-71L Student Seminar in Mathematics and Data: Stochastic Optimization
Number of participants limited to 12.

401-3620-20L Student Seminar in Statistics: Inference in Some Non-Standard Regression Problems
Number of participants limited to 24.
Mainly for students from the Mathematics Bachelor and Master Programmes who, in addition to the introductory course 401-2604-00L Probability and Statistics, have heard at least one core or elective course in statistics. Also offered in the Master Programmes Statistics resp. Data Science.

Abstract
Review of some non-standard regression models and the statistical properties of estimation methods in such models.

Objective
The main goal is for the students to discover some less known regression models which either generalize the well-known linear model (for example, monotone regression) or violate some of the most fundamental assumptions (as in shuffled or unlinked regression models).

Content
Linear regression is one of the most used models for prediction and hence one of the most understood in statistical literature. However, linearity might be too simplistic to capture the actual relationship between some response and given covariates. Also, there are many real data problems where linearity is plausible but the actual pairing between the observed covariates and responses is completely lost or at least partially. In this seminar, we review some of the non-classical regression models and the statistical properties of the estimation methods considered by well-known statisticians and machine learners. This will encompass:
1. Monotone regression
2. Single index model
3. Unlinked regression

401-3910-71L Student Seminar on Reinforcement Learning
Number of participants limited to 12.

Abstract
The aim of this seminar is to give an introduction to some of the mathematical ideas behind reinforcement learning. This includes stochastic optimisation and convergence analysis. The emphasis is on mathematical theory, not on developing and testing algorithms.

Objective
The aim of this seminar is to give an introduction to some of the mathematical ideas behind reinforcement learning. This includes stochastic optimisation and convergence analysis. The emphasis is on mathematical theory, not on developing and testing algorithms.

Content
The aim of this seminar is to give an introduction to some of the mathematical ideas behind reinforcement learning. This includes stochastic optimisation and convergence analysis. The emphasis is on mathematical theory, not on developing and testing algorithms.

Literature
See the seminar homepage at https://metaphor.ethz.ch/x/2021/hs/401-3910-71L

Prerequisites / notice
The students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

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Literature
See the seminar homepage at https://metaphor.ethz.ch/x/2021/hs/401-3910-71L

Prerequisites / notice
The students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

Semester Papers
There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

Number Title Type ECTS Hours Lecturers
401-3750-01L Semester Paper W 8 credits 11A Supervisors

Abstract
Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required. For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Prerequisites / notice
There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.
Semester Paper (No. 2)  ■

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required.

For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Abstract

Semester Papers help to deepen the students' knowledge of a specific subject area. Students are offered a selection of topics. These papers serve to develop the students' ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.

Prerequisites / notice

There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

Semester Paper (No. 3)  ■

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required.

For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Abstract

Semester Papers help to deepen the students' knowledge of a specific subject area. Students are offered a selection of topics. These papers serve to develop the students' ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.

Prerequisites / notice

There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

GESS Science in Perspective

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree. See https://ethz.ch/content/dam/ethz/common/docs/weisungssammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.)

Recommended Science in Perspective (Type B) for D-MATH.

Master's Thesis

Number Title Type ECTS Hours Lecturers

401-2000-00L Scientific Works in Mathematics O 0 credits M. Burger

Target audience: Third year Bachelor students; Master students who cannot document to have received an adequate training in working scientifically.

Abstract

Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)

Objective

Learn the basic standards of scientific works in mathematics.

Content

- Types of mathematical works
  - Publication standards in pure and applied mathematics
  - Data handling
  - Ethical issues
  - Citation guidelines

Prerequisites / notice


401-2000-01L Lunch Sessions – Thesis Basics for Mathematics Students Details and registration for the optional MathBib training course: https://www.math.ethz.ch/mathbib-schulungen Z 0 credits Speakers

Abstract

Optional MathBib training course

401-4990-00L Master's Thesis O 30 credits 57D Supervisors

Only students who fulfill the following criteria are allowed to begin with their Master's thesis:

a. successful completion of the Bachelor's programme;
b. fulfilling of any additional requirements necessary to gain admission to the Master's programme.

Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics is required.

For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Abstract

The master's thesis concludes the study programme. Writing up the master's thesis allows students to independently produce a major piece of work on a mathematical topic. It generally involves consulting the literature, solving any ensuing problems, and putting together the results in writing.

Additional Courses

Number Title Type ECTS Hours Lecturers

401-5000-00L Zurich Colloquium in Mathematics E- 0 credits R. Abgrall, M. Iacobelli, A. Bandeira, A. Iozzi, S. Mishra, R. Pandharipande, University
401-5990-00L  Zurich Graduate Colloquium  E-  0 credits  1K  A. Ioizzi, further speakers

Abstract
The Graduate Colloquium is an informal seminar aimed at graduate students and postdocs whose purpose is to provide a forum for communicating one's interests and thoughts in mathematics.

401-4530-00L  Geometry Graduate Colloquium  E-  0 credits  1K  Speakers

401-5110-00L  Number Theory Seminar  E-  0 credits  1K  Ö. Imamoglu, E. Kowalski, R. Pink, G. Wüstholz

401-5350-00L  Analysis Seminar  E-  0 credits  1K  A. Carlotto, F. Da Lio, A. Figalli, N. Hungerbühler, M. Iacobelli, T. Ilmanen, L. Keller, T. Rivière, J. Serra, University lecturers

401-5370-00L  Ergodic Theory and Dynamical Systems  E-  0 credits  1K  M. Burger, M. Einsiedler, P. Feller, A. Ioizzi, U. Lang, University lecturers

401-5530-00L  Geometry Seminar  E-  0 credits  1K  M. Burger, M. Einsiedler, P. Feller, G. Wüstholz

401-5580-00L  Symplectic Geometry Seminar  E-  0 credits  1K  P. Biran, A. Cannas da Silva

401-5330-00L  Talks in Mathematical Physics  E-  0 credits  1K  P. E. Y. Bousseau, A. Cattaneo, G. Felder, M. Gab Ariel, G. M. Graf, T. H. Willwacher

401-5650-00L  Zurich Colloquium in Applied and Computational Mathematics  E-  0 credits  1K  R. Abgrall, R. Alafifar, H. Ammari, R. Hiptmair, S. Mishra, S. Sauter

401-5600-00L  Seminar on Stochastic Processes  E-  0 credits  1K  J. Bertoin, A. Nikeghbali, B. D. Schlein, V. Tassion, W. Werner


Abstract
About 5 talks on applied statistics. See how statistical methods are applied in practice. There will be about 5 talks on how statistical methods are applied in practice. This is no lecture. There is no exam and no credit points will be awarded. The current program can be found on the web: http://stat.ethz.ch/events/zuko6st
Course language is English or German and may depend on the speaker.

401-5680-00L  Foundations of Data Science Seminar  E-  0 credits  1K  P. L. Bühlmann, A. Bandeira, H. Bölcskei, F. Yang

401-5660-00L  DACO Seminar  E-  0 credits  1K  A. Bandeira

401-5910-00L  Talks in Financial and Insurance Mathematics  E-  0 credits  1K  B. Acciaio, P. Cheridito, D. Prima, M. Schweizer, J. Teichmann, M. V. Wüthrich

Abstract
Regular research talks on various topics in mathematical finance and actuarial mathematics

401-5900-00L  Optimization Seminar  E-  0 credits  1K  A. Bandeira, R. Weismantel, R. Zenklusen

Abstract
Lectures on current topics in optimization
Exposure graduate students to ongoing research activities (including applications) in the domain of optimization.
This seminar is a forum for researchers interested in optimization theory and its applications. Speakers are expected to stimulate discussions on theoretical and applied aspects of optimization and related subjects. The focus is on efficient algorithms for continuous and discrete optimization problems, complexity analysis of algorithms and associated decision problems, approximation algorithms, mathematical modeling and solution procedures for real-world optimization problems in science, engineering, industries, public sectors etc.

401-5960-00L  Colloquium on Mathematics, Computer Science, and Education  E-  0 credits  1K  N. Hungerbühler, M. Akved, D. Grawehr Morath, J. Hromkovic, P. Spindler

Abstract
Didactics colloquium

The Zurich Physics Colloquium

Abstract

Research colloquium

The Zurich Theoretical Physics Colloquium

Abstract

Research colloquium

The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

Computer Science Colloquium

Abstract

Invited talks, covering the entire scope of computer science. External Listeners are welcome at no charge. A detailed schedule is published at the beginning of each semester.

Objective

Top international computer scientists take the floor at the distinguished computer science colloquium. Our guest speakers present impacting topics across various areas of the discipline. The colloquium series is held every semester and also includes inaugural and farewell lectures of the department’s professors. The colloquium is a noteworthy event for all graduate students. Outside attendance is equally welcome.

Content

Eingeladene Vorträge aus dem gesamten Bereich der Informatik, zu denen auch Auswärtige kostenlos eingeladen sind. Zu Semesterbeginn erscheint jeweils ein ausführliches Programm.

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-2004-AAL</td>
<td>Algebra II</td>
<td>E-</td>
<td>5 credits</td>
<td>11R</td>
<td>M. Burger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit. Galois theory and related topics. The precise content changes with the examiner. Candidates must therefore contact the examiner in person before studying the material.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Introduction to fundamentals of field extensions, Galois theory, and related topics.</td>
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<tr>
<td>Content</td>
<td>The main topic is Galois Theory. Starting point is the problem of solvability of algebraic equations by radicals. Galois theory solves this problem by making a connection between field extensions and group theory. Galois theory will enable us to prove the theorem of Abel-Ruffini, that there are polynomials of degree 5 that are not solvable by radicals, as well as Galois’ theorem characterizing those polynomials which are solvable by radicals.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Galois Theory is the topic treated in Chapter A5. Algebra I, in Rotman’s book this corresponds to the topics treated in the Chapters A3 and A4.</td>
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<tr>
<td>406-2005-AAL</td>
<td>Algebra I and II</td>
<td>E-</td>
<td>12 credits</td>
<td>26R</td>
<td>M. Burger, M. Einsiedler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit. Introduction and development of some basic algebraic structures - groups, rings, fields including Galois theory, representations of finite groups, algebras. The precise content changes with the examiner. Candidates must therefore contact the examiner in person before studying the material.</td>
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<tr>
<td>Objective</td>
<td>Basic notions and examples of groups; Subgroups, Quotient groups and Homomorphisms, Group actions and applications Basic notions and examples of rings; Ring Homomorphisms, ideals, and quotient rings, rings of fractions Euclidean domains, Principal ideal domains, Unique factorization domains Field extensions, Algebraic extensions, Classical straight edge and compass constructions</td>
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<tr>
<td>Content</td>
<td>Basic notions and examples of fields; Fundamentals of Galois theory Representation theory of finite groups and algebras</td>
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</tr>
<tr>
<td>406-2303-AAL</td>
<td>Complex Analysis</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>T. H. Willwacher</td>
</tr>
<tr>
<td>Abstract</td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit. Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, conformal mappings, Riemann mapping theorem.</td>
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<tr>
<td>Literature</td>
<td></td>
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</tr>
</tbody>
</table>

Mathematics Master - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture | P | practical/laboratory course |
| G | lecture with exercise | A | independent project |
| U | exercise | D | diploma thesis |
| S | seminar | R | revision course / private study |

ECTS | European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Micro- and Nanosystems Master

Core Courses

Devices and Systems

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0166-00L</td>
<td>Analog Integrated Circuits</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>T. Jang</td>
</tr>
</tbody>
</table>

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature

Energy Conversion and Quantum Phenomena

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0913-00L</td>
<td>Introduction to Photonics</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>R. Quidant, J. Ortega Arroyo</td>
</tr>
</tbody>
</table>

Abstract
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

Objective
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
I- BASICS OF WAVE THEORY
   1) General concepts
   2) Differential wave equation
   3) Wavefront
   4) Plane waves and Fourier decomposition of optical fields
   5) Spherical waves and Huygens-Fresnel principle

II- ELECTROMAGNETIC WAVES
   1) Maxwell equations
   2) Wave equation for EM waves
   3) Dielectric permittivity
   4) Refractive index
   5) Nonlinear optics
   6) Polarization and polarization control

III- PROPAGATION OF LIGHT
   1) Waves at an interface
   2) The Fresnel equations
   3) Total internal reflection
   4) Evanescent waves
   5) Dispersion diagram

IV- INTERFERENCES
   1) General considerations
   2) Temporal and spatial coherence
   3) The Young double slit experiment
   4) Diffraction gratings
   5) The Michelson interferometer
   6) Multi-wave interference
   7) Antireflecting coating and interference filters
   8) Optical holography

V- LIGHT MANIPULATION
   1) Optical waveguides
   2) Photonic crystals
   3) Metamaterials and metasurfaces
   4) Optical cavities

VI- INTRODUCTION TO OPTICAL MICROSCOPY
   1) Basic concepts
   2) Direct and Fourier imaging
   3) Image formation
   4) Fluorescence microscopy
   5) Scattering-based microscopy
   6) Digital holography
   7) Computational imaging

VII- OPTICAL FORCES AND OPTICAL TWEEZERS
   1) History of optical forces
   2) Theory of optical trapping
   3) Atom cooling
   4) Optomechanics
   5) Plasmonic trapping
   6) Applications of optical tweezers

Lecture notes
Class notes and handouts
Literature
Optics (Hecht) - Pearson
Prerequisites / notice
Physics I, Physics II

Semiconductor Nanostructures

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lectures</th>
<th>T. M. Ihn</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0595-00L</td>
<td></td>
<td>6</td>
<td>2+1</td>
<td>T. Ihn</td>
</tr>
</tbody>
</table>

Abstract
The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

Objective
At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:
   1. The integer quantum Hall effect
   2. Conductance quantization in quantum point contacts
   3. The Aharonov-Bohm effect
   4. Coulomb blockade in quantum dots

Content
1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

Lecture notes
Material, Surfaces and Properties

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0509-00L</td>
<td>Microscale Acoustofluidics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>J. Dual</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Understanding acoustophoresis, the design of devices and potential applications.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity. Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microrobotics to surface acoustic wave devices.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<td>Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.</td>
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</tbody>
</table>

Taught competencies

**Domain A - Subject-specific Competencies**

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

**Domain B - Method-specific Competencies**

- Analytical Competencies: assessed
- Media and Digital Technologies: assessed
- Problem-solving: not assessed

**Domain C - Social Competencies**

- Communication: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed

**Domain D - Personal Competencies**

- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-direction and Self-management: not assessed

---

151-0524-00L  Continuum Mechanics I

Abstract

The lecture deals with constitutive models that are relevant for design and calculation of structures. These include anisotropic linear elasticity, linear viscoelasticity, plasticity, viscoplasticity. Homogenization theories and laminate theory are presented. Theoretical models are complemented by examples of engineering applications and experiments.

Objective

Basic theories for solving continuum mechanics problems of engineering applications, with particular attention to material models.

Content

Anisotropic elasticity, Linear elastic and linear viscous material behavior, Viscoelasticity, Micro-macro modelling, Laminate theory, Plasticity, Viscoplasticity, Examples of engineering applications, Comparison with experiments.

Lecture notes

Yes

---

151-0902-00L  Micro- and Nanoparticle Technology

Abstract

Particles are everywhere and nano is the new scale in science & engineering as micro was ~200 years ago. For highly motivated students, this exceptionally demanding class gives a flavor of nanotechnology with hands-on student projects on gas-phase particle synthesis & applications capitalizing on particle dynamics (diffusion, coagulation etc.), shape, size distribution and characterization.

Objective

This course aims to familiarize motivated M/BSc students with some of the basic phenomena of particles at the nanoscale, thereby illustrating the links between physics, chemistry, materials science through hands-on experience. Furthermore it aims to give an overview of the field with motivating lectures from industry and academia, including the development of technologies and processes based on particle technology with introduction to design methods of mechanical processes, scale-up laws and optimal use of materials and energy.

Most importantly, this course aims to develop the creativity and sharpen the communication skills of motivated students through their individual projects, a PERFECT preparation for the M/BSc thesis (e.g. efficient & critical literature search, effective oral/written project presentations), the future profession itself and even life, in general, are always there!
Content
The course objectives are best met primarily through the individual student projects which may involve experiments, simulations or critical & quantitative reviews of the literature. Projects are conducted individually under the close supervision of MSc, PhD or post-doctoral students. Therein, a 2-page proposal is submitted within the first two semester weeks addressing explicitly, at least, 10 well-selected research articles and thoughtful meetings with the project supervisor. The proposal address 3 basic questions: a) how important is the project; b) what has been done already in that field and c) what will be done by the student. Detailed feedback on each proposal is given by the supervisor, assistant and professor two weeks later. Towards the end of the semester, a 10-minute oral presentation is given by the student followed by 10 minutes Q&A. A 10-page final report is submitted by noon of the last day of the semester. The project supervisor will provide guidance throughout the course. Lectures include some of the following:
- Overview & Project Presentation
- Particle Size Distribution
- Particle Diffusion
- Coagulation
- Agglomeration & Coalescence
- Particle Growth by Condensation
- Control of particle size & structure during gas-phase synthesis
- Multi-scale design of aerosol synthesis of particles
- Particle Characterization
- Aerosol manufacture of nanoparticles
- Forces acting on Single Particles in a Flow Field
- Fixed and Fluidized Beds
- Separations of Solid-Liquid & Solid-Gas systems
- Emulsions/droplet formation/microfluidics
- Gas Sensors
- Coaching for proposal & report writing as well as oral presentations

Literature

Prerequisites / notice
FluidMechanik I, Thermodynamik I&II & "clean" 5th semester BSc student standing in D-MAVT (no block 1 or 2 obligations). Students attending this course are expected to allocate sufficient additional time within their weekly schedule to successfully conduct their project. As exceptional effort will be required! Having seen "Chasing Mavericks" (2012) by Apted & Henson, "Unbroken" (2014) by Angelina Jolie and, in particular, "The Salt of the Earth" (2014) by Wim Wenders might be helpful and even motivating. These movies show how methodic effort can bring superior and truly unexpected results (e.g. stay under water for 5 minutes to overcome the fear of riding huge waves or merciless Olympic athlete training that help survive 45 days on a raft in Pacific Ocean followed by 2 years in a Japanese POW camp during WWII).

327-0505-00L Surfaces, Interfaces and their Applications I

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
<th>2V+1U</th>
<th>4G</th>
<th>N. Spencer, M. P. Heuberger, L. Isa</th>
</tr>
</thead>
</table>

Objective
To gain an understanding of the physical and chemical principles, as well as the tools and applications of surface science, and to be able to choose appropriate surface-analytical approaches for solving problems.

Content
Introduction to Surface Science
Physical Structure of Surfaces
Surface Forces (static and dynamic)
Adsorbates on Surfaces
Surface Thermodynamics and Kinetics
The Solid-Liquid Interface
Electron Spectroscopy
Vibrational Spectroscopy on Surfaces
Scanning Probe Microscopy
Introduction to Tribology
Introduction to Corrosion Science

Lecture notes
Script Download:
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

Literature
Script Download:
https://moodle-app2.let.ethz.ch/course/view.php?id=14993

Prerequisites / notice
Chemistry:
General undergraduate chemistry
including basic chemical kinetics and thermodynamics

Physics:
General undergraduate physics
including basic theory of diffraction and basic knowledge of crystal structures

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving
assessed

Domain D - Personal Competencies
Creative Thinking
Cultural Thinking
assessed

Modelling and Simulation

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCSE)</td>
<td>W</td>
<td>4 credits</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
</tr>
</tbody>
</table>

Abstract
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.
With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)

2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)

3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models

4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

### Lecture notes

https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/

Class notes, handouts

### Literature

- An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann
- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann
- Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press
- Lecture notes

### Prerequisites

- Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.
- The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

### Physical Modelling and Simulation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W+</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
</tr>
</tbody>
</table>

### Objective

- An introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.
- Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own simple field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

### Content

- The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetic, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

- In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

### Laboratory Course

#### Embedded MEMS Lab

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0620-00L</td>
<td>Embedded MEMS Lab</td>
<td>W+</td>
<td>5</td>
<td>3P</td>
<td>C. Hierold, S. Blunier, M. HaIuska</td>
</tr>
</tbody>
</table>

### Abstract

Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report. Limited access

### Objective

- Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

### Content

- With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
  - Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
  - Packaging and electrical connection of a MEMS device
  - Testing and characterization of the MEMS device
  - Written documentation and evaluation of the entire production, processing and characterization

### Lecture notes

A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

### Literature

The document provides sufficient information for the participants to successfully participate in the course.
Participating students are required to attend all scheduled lectures and meetings of the course.

Participating students are required to provide proof that they have personal accident insurance prior to the start of the laboratory portion of the course.

For safety and efficiency reasons the number of participating students is limited. We regret to restrict access to this course by the following rules:

Priority 1: master students of the master's program in "Micro and Nanosystems"

Priority 2: master students of the master's program in "Mechanical Engineering" with a specialization in Microsystems and Nanoscale Engineering (MAVT-tutors Profs Daraio, Dual, Hierold, Kaumoutsakos, Neltso, Nors, Poulkakos, Pratsinis, Stemmer), who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 3: master students, who attended the bachelor course "151-0621-00L Microsystems Technology" successfully.

Priority 4: all other students (PhD, bachelor, master) with a background in silicon or Microsystems process technology.

If there are more students in one of these priority groups than places available, we will decide by (in following order) best achieved grade from 151-0621-00L Microsystems Technology, registration to this practicum at previous semester, and by drawing lots.

Students will be notified at the first lecture of the course (introductory lecture) as to whether they are able to participate.

The course is offered in autumn and spring semester.

## Elective Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-0409-00L</td>
<td>Multiphysics Modeling and Simulation</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>C. I. Roman</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are defined by devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as unexperienced users will soon find themselves in front of frustrating error messages or incomprehensible results. It is the role of this course to show how to properly set up a problem by exposing common misconceptions and pitfalls in multiphysics modeling. Good practices will be taught that should significantly speed-up the modeling process and produce results that do not contradict intuition. Examples will mainly come from the fields of mechanics (continuum mechanics), electromagnetism (Maxwell equations), heat transport (Fourier equation) and combinations of these domains.</td>
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<td>Content</td>
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<td></td>
<td>- Recap of ordinary and partial differential equations (ODEs and PDEs) concepts</td>
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<td></td>
<td>- Existence and uniqueness of solutions; well- and ill-posed problems</td>
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<td></td>
<td>- Time integration and (non)linear solvers</td>
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<td>- Boundary conditions and constraints</td>
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<td>- Approximate and simplified formulations; domains of applicability</td>
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<td></td>
<td>- Discretization and numerical solutions for differential equations</td>
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<td>- Solution-appropriate meshing; multiscale, local/global adaptive meshing</td>
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<td></td>
<td>- Geometry simplification</td>
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<td></td>
<td>- Model order reduction, coarsening</td>
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<td></td>
<td>- Coupling and segregation/decoupling of multiphysics</td>
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<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Lecture handouts will be posted online.</td>
</tr>
<tr>
<td>151-0525-00L</td>
<td>Dynamic Behavior of Materials</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>D. Mohr, C. Roth, T. Tancogne-Dejean</td>
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<td>Note: previous course title until HS19 “Wave Propagation in Solids”.</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td>Lectures and computer labs concerned with the modeling of the deformation response and failure of engineering materials (metals, polymers and composites) subject to extreme loadings during manufacturing, crash, impact and blast events. Students will learn to apply, understand and develop computational models of a large spectrum of engineering materials to predict their dynamic deformation response and failure in finite element simulations. Students will become familiar with important dynamic testing techniques to identify material model parameters from experiments. The ultimate goal is to provide the students with the knowledge and skills required to engineer modern multi-material solutions for high performance structures in automotive, aerospace and naval engineering.</td>
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<tr>
<td></td>
<td>Content</td>
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<td></td>
<td>Topics include temperature and strain rate dependent elasto-plasticity, dynamic brittle and ductile fracture; impulse transfer, impact and wave propagation in solids; computational aspects of material model implementation; simulation of dynamic failure of structures;</td>
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<tr>
<td></td>
<td>Literature</td>
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<td>Slides of the lectures, relevant journal papers and user manuals will be provided.</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Literature</td>
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<td>Various books will be recommended pertaining to the topics covered.</td>
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<tr>
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<td>Literature</td>
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<td></td>
<td>Course in continuum mechanics (mandatory), finite element method (recommended)</td>
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<td>151-0532-00L</td>
<td>Nonlinear Dynamics and Chaos I</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>G. Haller</td>
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<td>Taught competencies</td>
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<tr>
<td></td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Domain D - Personal Competencies</td>
<td>Critical Thinking</td>
<td>not assessed</td>
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</tbody>
</table>
Abstract
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device. 

Objective
Familiarize students with main architectural principles and concepts of embedded control systems.

Content
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

151-0593-00L Embedded Control Systems W 4 credits 6G J. S. Freudenberg, M. Schmid Daners

151-0605-00L Nanosystems W 4 credits 4G A. Stemmer

Abstract
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles. 

Objective
Familiarize students with basic science and engineering principles governing the nano domain.

Content
(1) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

Self-assembly and directed assembly of 2D and 3D structures.

Special emphasis on the emerging field of molecular electronic devices.

Familiarize students with main architectural principles and concepts of embedded control systems.

Self-assembly and directed assembly of 2D and 3D structures.

The course addresses basic science and engineering principles governing the nano domain. We particularly work out the links between topics that are traditionally taught separately. Familiarity with basic concepts of quantum mechanics is expected.

Special emphasis is placed on the emerging field of molecular electronic devices, their working principles, applications, and how they may be assembled.

Topics are treated in 2 blocks:

(I) From Quantum to Continuum
From atoms to molecules to condensed matter: characteristic properties of simple nanosystems and how they evolve when moving towards complex ensembles.

(II) Interaction Forces on the Micro and Nano Scale
Intermolecular forces, their macroscopic manifestations, and ways to control such interactions.

Self-assembly and directed assembly of 2D and 3D structures.


Introduction to Plasmonics

N. Yazdani

Solid State Electronics and Optics
- Introduction to microsystems technology (MST) and micro electro mechanical systems (MEMS)
- Scientific presentations from the field of Micro- and Nanosystems

The course addresses the physical principles of modern semiconductor devices, and the foundations of their modeling and numerical simulations. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects supplement the lectures.

The course aims at the understanding of the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Prerequisites / notice
- Undergraduate physics, mathematics, semiconductor devices

Semiconductor Devices: Physical Bases and Simulation

A. Schenk, C. I. Roman

Semiconductor Devices: Physical Bases and Simulation
- The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation.
- The course aims at the understanding of the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented orally and as a written paper.

The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Prerequisites / notice
- Undergraduate physics, mathematics, semiconductor devices

Semiconductor Devices: Physical Bases and Simulation
- The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation.
- The course aims at the understanding of the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Each student selects a paper (list distributed in class) and expands the topic into a Mini-Review that illuminates the particular field beyond the immediate results reported in the paper. Each Mini-Review will be presented orally and as a written paper.

The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Prerequisites / notice
- Undergraduate physics, mathematics, semiconductor devices

Solid State Electronics and Optics
- "Solid State Electronics" is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magnetoresistance, and optical properties of solids.
- Practical applications will be demonstrated on case studies.
Content  
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions.

The exercises are focused on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes / literature  
The script (in book style) can be downloaded from: [https://iis-students.ee.ethz.ch/lectures/](https://iis-students.ee.ethz.ch/lectures/)
The script (in book style) is sufficient. Further reading will be recommended in the lecture.

Prerequisites / notice  

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
<th>5G</th>
<th>A. Iannelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0225-00L</td>
<td>Linear System Theory</td>
<td>Linear System Theory</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Abstract</td>
<td>The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems.</td>
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<tr>
<td>Objective</td>
<td>Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.</td>
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</tbody>
</table>
| Content | - Proof techniques and practices.  
- Linear spaces, normed linear spaces and Hilbert spaces.  
- Ordinary differential equations, existence and uniqueness of solutions.  
- Continuous and discrete time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.  
- Controllability and observability, duality. Time invariant systems treated as a special case.  
- Stability and stabilization, observers, state and output feedback, separation principle. |
| Taught competencies | Domain A - Subject-specific Competencies  
Concepts and Theories | assessed |
| Domain B - Method-specific Competencies  
Analytical Competencies | assessed |
| Domain D - Personal Competencies  
Creative Thinking | not assessed |
| Literature | No course notes will be distributed in class. Available on the course Moodle platform. |

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>W</th>
<th>3V+2U</th>
<th>T. Zambelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0311-00L</td>
<td>Qubits, Electrons, Photons</td>
<td>Qubits, Electrons, Photons</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Abstract</td>
<td>In-depth analysis of the quantum mechanics origin of nuclear magnetic resonance (qubits, two-level systems), of LASER (quantization of the electromagnetic field, photons), and of electron transfer (from electrochemistry to photosynthesis).</td>
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<tr>
<td>Objective</td>
<td>Beside electronics nanodevices, D-ITET is pushing its research in the fields of NMR (MRI), electrochemistry, bioelectronics, nano-optics, and quantum information, which are all rationalized in terms of quantum mechanics.</td>
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</tr>
</tbody>
</table>
| Content | - Lagrangian and Hamiltonian: Symmetries and Poisson Brackets  
- Postulates of QM: Hilbert Spaces and Operators  
- Heisenberg’s Matrix Mechanics: Hamiltonian and Time Evolution Operator  
- Spin: Qubits, Bloch Equations, and NMR  
- Entanglement  
- Symmetries and Corresponding Operators  
- Schrödinger's Wave Mechanics: Electrons in a Periodic Potential and Energy Bands  
- Harmonic Oscillator: Creation and Annihilation Operators  
- Identical Particles: Bosons and Fermions  
- Quantization of the Electromagnetic Field: Photons, Absorption and Emission, LASER  
- Electron Transfer: Marcus Theory via Born-Oppenheimer, Franck-Condon, Landau-Zener |
| Literature | No lecture notes because the proposed textbooks together with the provided supplementary material are more than exhaustive! |
| Notice | The course has been intentionally conceived to be self-consistent with respect to QM for those master students not having encountered it in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) QM introduction course like the D-ITET “Physics II”. |

Supplementary material will be uploaded in Moodle.

**NOTES:**
- "Physics I" and "Physics II" in their track yet. Therefore, a presumably large overlapping has to be expected with a (welcome!) Quantum Mechanics course like the D-ITET "Physics II".

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in Moodle!
This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.

Prerequisites / notice
Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

Lecture notes
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

Prerequisites: Recommended (but not required): Stochastic models and signal processing, Communication Electronics, Analog Integrated Circuits, Transmission Lines and Filters.

Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria ...) and of the main properties of linear systems is necessary.

Lecture notes
The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.
Nano-Optics

Abstract
The measurement process is at the heart of both science and engineering. Electromagnetic fields have proven to be particularly powerful probes. This course provides the basic knowledge necessary to understand current state-of-the-art optomechanical measurement systems operating at the precision limits set by the laws of quantum mechanics.

Objective
The goal of this course is to understand the fundamental limitations of measurement systems relying on electromagnetic fields.

Content
The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insights at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics.

Prerequisites / notice
1. Electrodynamics
2. Physics 1,2
3. Introduction to quantum mechanics

Quantum Science with Superconducting Circuits

This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ applied for scientific simulations.

Superconducting Circuits provide a versatile experimental platform to explore the most intriguing quantum-physical phenomena and constitute one of the prime contenders to build quantum computers. Students will get a thorough introduction to the underlying physical concepts, the experimental setting, and the state-of-the-art of quantum computing in this emerging research field.

We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical tweezers.

Prerequisites / notice
- Electromagnetic fields and waves (or equivalent)
- Physics I+II

Programming Techniques for Scientific Simulations I

Abstract
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

Objective
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

Prerequisites / notice
All students and researchers with a general interest in quantum information science, quantum optics, and quantum engineering are welcome to this course. Basic knowledge of quantum physics is a plus, but not a strict requirement for the successful participation in this course.

Molecular Aspects of Catalysts and Surfaces

Abstract
Basic elements of surface science important for materials and catalysis research. Physical and chemical methods important for research in surface science, material science and catalysis are considered and their application is demonstrated on practical examples.

Objective
Basic aspects of surface science. Understanding of principles of most important experimental methods used in research concerned with surface science, material science and catalysis.

Content
Methods which are covered embrace: Gas adsorption and surface area analysis, IR-Spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy, X-ray absorption, solid state NMR, Electron Microscopy and others.
Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

Prerequisites

Pre requisite: Basic knowledge on unit operations, mainly reaction engineering and distillation. It is recommended that the student takes the module "Process Simulation and Flowsheeting" before "Process Design and Development", but it is not mandatory.

701-1239-00L Aerosols I: Physical and Chemical Principles 4 credits 2V+1U M. Gysel Beer, D. Bell, E. Weingartner

Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

Environmental impacts:
The students...
- know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
- understand the major important climate impacts of atmospheric aerosols.
- are aware of the health impacts of atmospheric aerosols.

Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making not assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies

Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies

Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking not assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

752-3103-00L Food Rheology I 3 credits 2V P. A. Fischer

Food Rheology I

Rheology is the science of flow and deformation of matter such as polymers, dispersions (emulsions, foams, suspensions), and colloidal systems. The fluid dynamical basis, measuring techniques (rheometry), and the flow properties of different fluids (Newtonian, non-Newtonian, viscoelastic) are introduced and discussed.

Objective

The course provides an introduction on the link between flow and structural properties of flowing material. Rheometrical techniques and appropriate measuring protocols for the characterization of complex fluids will be discussed. The concept of rheological constitutive equations and the application to different material classes are established.

Content

Lectures will be given on general introduction (4h), fluid dynamics (2h), complex flow behavior (4h), influence of temperature (2h), rheometers (4h), rheological tests (6h) and structure and rheology of complex fluids (4h).

Lecture notes

Notes will be handed out during the lectures.

Literature

Provided in the lecture notes.

► Multidisciplinary Courses

The students are free to choose individually from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich
## GESS Science in Perspective

- see GESS Science in Perspective: Language Courses
  ETH/UBZH
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended GESS Science in Perspective (Type B) for D-MAVT.

### Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1007-00L</td>
<td>Semester Project Micro- and Nanosystems</td>
<td>O</td>
<td>8 credits</td>
<td>17A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

**Abstract**

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

**Objective**

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

### Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-1090-00L</td>
<td>Industrial Internship</td>
<td>O</td>
<td>8 credits</td>
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<td>external organisers</td>
</tr>
</tbody>
</table>

**Abstract**

No registration required via myStudies.

**Objective**

The main objective of the minimum twelve-week internship is to expose Master’s students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

### Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1006-00L</td>
<td>Master's Thesis Micro- and Nanosystems</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
</tbody>
</table>

**Abstract**

Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

**Objective**

The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

---

**Micro- and Nanosystems Master - Key for Type**

| O  | Compulsory | E-  | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z   | Courses outside the curriculum |
| W  | Eligible for credits | Dr  | Suitable for doctorate |

**Key for Hours**

| V  | lecture | P   | practical/laboratory course |
| G  | lecture with exercise | A   | independent project |
| U  | exercise | D   | diploma thesis |
| S  | seminar | R   | revision course / private study |
| K  | colloquium |

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Exchange Students

Courses for Exchange Students

Prepare a study plan

In case the course catalogue of the upcoming semester is not available yet, please expect it to be like the year before.

You can study at ETH Zurich as an exchange student for 1 or 2 semesters, starting in the autumn or in the spring semester.

Exchange students may choose courses from different curricula and years, provided that at least two thirds of all courses are taken in the ETH Zurich department they are registered in. Please be sure to coordinate your schedule with your home university.

Exam sessions and End-of-semester examinations

Like all ETH Zurich students, exchange students are obliged to sit their exams during the official examination periods. Students are requested to be present at ETH Zurich during these periods. You are therefore expected to plan your studies, internships, jobs, and financial means accordingly.

Research Project

The courses below are only available for exchange students.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>900-0005-00L</td>
<td>5 Credit Project</td>
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<td>5 credits</td>
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<td></td>
<td>ONLY for mobility students.</td>
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<td></td>
<td>Any other students (e.g.BSc, MSc, doctoral students) CANNOT enrol for this course unit.</td>
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<tr>
<td>900-0010-00L</td>
<td>10 Credit Project</td>
<td>W</td>
<td>10 credits</td>
<td>21A</td>
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<tr>
<td>900-0015-00L</td>
<td>15 Credit Project</td>
<td>W</td>
<td>15 credits</td>
<td>32A</td>
<td>Lecturers</td>
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<tr>
<td>900-0020-00L</td>
<td>20 Credit Project</td>
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<td>20 credits</td>
<td>43A</td>
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<td>Any other students (e.g.BSc, MSc, doctoral students) CANNOT enrol for this course unit.</td>
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<tr>
<td>900-0025-00L</td>
<td>25 Credit Project</td>
<td>W</td>
<td>25 credits</td>
<td>54A</td>
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<td>Any other students (e.g.BSc, MSc, doctoral students) CANNOT enrol for this course unit.</td>
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<tr>
<td>900-0030-00L</td>
<td>30 Credit Project</td>
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<td>30 credits</td>
<td>64A</td>
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<td>Any other students (e.g.BSc, MSc, doctoral students) CANNOT enrol for this course unit.</td>
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<tr>
<td>900-0060-00L</td>
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<td>W</td>
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</table>

Additional Courses

by individual arrangement

Exchange Students - Key for Type

| O      | Compulsory                       | E-   | Recommended, not eligible for credits |
| W+     | Eligible for credits and recommended | Z    | Courses outside the curriculum |
| W      | Eligible for credits             | Dr   | Suitable for doctorate |

Key for Hours

| V      | lecture                        | P    | practical/laboratory course |
| G      | lecture with exercise           | A    | independent project |
| U      | exercise                       | D    | diploma thesis |
| S      | seminar                        | R    | revision course / private study |
| K      | coloquium                      |      |                           |

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Neural Systems and Computation Master

Core Courses

Compulsory Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1039-00L</td>
<td>Basics of Instrumentation, Measurement, and Analysis (University of Zurich)</td>
<td>O</td>
<td>4</td>
<td>9S</td>
<td>S.-C. Liu, T. Dalbrück, R. Hahnloser, G. Indiveri, V. Mante, P. Pyk, D. Scaramuzza, W. von der Behrens</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI502

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.shtml

Abstract

Experimental data are always as good as the instrumentation and measurement, but never any better. This course provides the very basics of instrumentation relevant to neurophysiology and neuromorphic engineering, it consists of two parts: a common introductory part involving analog signals and data acquisition (Part I), and a more specialized second part (Part II).

Objective

The goal of Part I is to provide a general introduction to the signal acquisition process. Students are familiarized with basic lab equipment such as oscilloscopes, function generators, and data acquisition devices. Different electrical signals are generated, visualized, filtered, digitized, and analyzed using Matlab (Mathworks Inc.) or Labview (National Instruments).

In Part II, the students are divided into small groups to work on individual measurement projects according to availability and interest. Students single-handedly solve a measurement task, making use of their basic knowledge acquired in the first part. Various signal sources will be provided.

Prerequisites / notice

For each part, students must hand in a written report and present a live demonstration of their measurement setup to the respective supervisor. The supervisor of Part I is the teaching assistant, and the supervisor of Part II is task specific. Admission to Part II is conditional on completion of Part I (report + live demonstration).

Reports must contain detailed descriptions of the measurement goal, the measurement procedure, and the measurement outcome. Either confidence or significance of measurements must be provided. Acquisition and analysis software must be documented.

<table>
<thead>
<tr>
<th>Number</th>
<th>Journal Club (University of Zurich)</th>
<th>O</th>
<th>2</th>
<th>1S</th>
<th>G. Indiveri</th>
</tr>
</thead>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI702

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.shtml

Abstract

The Neuroinformatics Journal club is a weekly meeting during which students present current research papers. The presentation last from 30 to 60 Minutes and is followed by a general discussion.

Objective

The Neuroinformatics Journal club aims to train students to present cutting-edge research clearly and efficiently. It leads students to learn about current topics in neurosciences and neuroinformatics, to search the relevant literature and to critically and scholarly appraise published papers. The students learn to present complex concepts and answer critical questions.

Content

Relevant current papers in neurosciences and neuroinformatics are covered.

<table>
<thead>
<tr>
<th>Number</th>
<th>Neuroinformatics - Colloquia (University of Zurich)</th>
<th>Z</th>
<th>0</th>
<th>1K</th>
<th>S.-C. Liu, R. Hahnloser, V. Mante</th>
</tr>
</thead>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI701

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.shtml

Abstract

The colloquium in Neuroinformatics is a series of lectures given by invited experts. The lecture topics reflect the current themes in neurobiology and neuromorphic engineering that are relevant for our Institute.

Objective

The goal of these talks is to provide insight into recent research results. The talks are not meant for the general public, but really aimed at specialists in the field.

Content

The topics depend heavily on the invited speakers, and thus change from week to week. All topics concern neural computation and their implementation in biological or artificial systems.

<table>
<thead>
<tr>
<th>Number</th>
<th>Readings in Neuroinformatics (University of Zurich)</th>
<th>O</th>
<th>3</th>
<th>1S</th>
<th>W. von der Behrens, R. Hahnloser, S.-C. Liu, V. Mante</th>
</tr>
</thead>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI431

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.shtml

Abstract

Thirteen major areas of research have been selected, which cover the key concepts that have led to our current ideas of how the nervous system is built and functions. We will read both original papers and explore the conceptual links between them and discuss the 'sociology' of science, the pursuit of basic science questions over a century of research.
It is commonplace that scientists rarely cite literature that is older than 10 years and when they do, they usually cite one paper that serves as the representative for a larger body of work that has long since been incorporated anonymously in textbooks. Even worse, many authors have not even read the papers they cite in their own publications. This course, ‘Foundations of Neuroscience’ is one antidote. Thirteen major areas of research have been selected. They cover the key concepts that have led to our current ideas of how the nervous system is built and functions. Unusually, we will explore these areas of research by reading the original papers, instead of reading a digested summary from a textbook or review. By doing this, we will learn how the discoveries were made, what instrumentation was used, how the scientists interpreted their own findings, and how their work, often over many decades and linked together with related findings from many different scientists, generate the current views of mechanism and structure of the nervous system. To give one concrete example, in 1890 Roy and Sherrington showed that there was a neural activity-dependent regulation of blood flow in the brain. One hundred years later, Ogawa discovered that they could use Nuclear Magnetic Resonance (NMR) to measure a blood oxygen-level dependent (BOLD) signal, which they showed was neural activity-dependent. This discovery led to the development of human functional Magnetic Resonance Imaging (fMRI), which has revolutionized neuropsychology and neuropsychiatry. We will read both these original papers and explore the conceptual links between them and discuss the ‘sociology’ of science, which in this case, the pursuit of basic science questions over a century of research, led to an explosion in applications. We will also explore the perils of researchers not having an intimate knowledge of the papers. Assessment will be in the form of a written exam where students will be given a paper and asked to write a short abstract of its contents.

Content
It is commonplace that scientists rarely cite literature that is older than 10 years and when they do, they usually cite one paper that serves as the representative for a larger body of work that has long since been incorporated anonymously in textbooks. Even worse, many authors have not even read the papers they cite in their own publications. This course, ‘Foundations of Neuroscience’ is one antidote. Thirteen major areas of research have been selected. They cover the key concepts that have led to our current ideas of how the nervous system is built and functions. Unusually, we will explore these areas of research by reading the original papers, instead of reading a digested summary from a textbook or review. By doing this, we will learn how the discoveries were made, what instrumentation was used, how the scientists interpreted their own findings, and how their work, often over many decades and linked together with related findings from many different scientists, generate the current views of mechanism and structure of the nervous system. To give one concrete example, in 1890 Roy and Sherrington showed that there was a neural activity-dependent regulation of blood flow in the brain. One hundred years later, Ogawa discovered that they could use Nuclear Magnetic Resonance (NMR) to measure a blood oxygen-level dependent (BOLD) signal, which they showed was neural activity-dependent. This discovery led to the development of human functional Magnetic Resonance Imaging (fMRI), which has revolutionized neuropsychology and neuropsychiatry. We will read both these original papers and explore the conceptual links between them and discuss the ‘sociology’ of science, which in this case, the pursuit of basic science questions over a century of research, led to an explosion in applications. We will also explore the perils of researchers not having an intimate knowledge of the papers. Assessment will be in the form of a written exam where students will be given a paper and asked to write a short abstract of its contents.

Objective
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today’s neuroscience papers. After this course students will be able to:
- read and understand the main ideas and methods that are presented in today’s neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to ‘error backpropagation’ in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Content
Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Mnih et al, 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve untrained performance to different and integrate out-of-domain data examples (data that they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Lecture notes
The lecture slides will be provided as a PDF after each lecture.

Prerequisites / notice
This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:
1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

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Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn.

Abstract
The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Objective
Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monodisciplines of physics, maths, computer science, engineering, biology, psychology and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

227-1051-00L Systems Neuroscience (University of Zurich) W 6 credits 2V+1U D. Kiper

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI415

Mind the enrolment deadlines at UZH:
https://www.uzh.ch/cmsssl/en/studies/application/deadline.html

Abstract
This course focuses on basic aspects of central nervous system physiology, including perception, motor control and cognitive functions.

Objective
To understand the basic concepts underlying perceptual, motor and cognitive functions.

Content
Main emphasis sensory systems, with complements on motor and cognitive functions.

Lecture notes
None

Literature

"Principles of Neural Science", Kandel, Schwartz, and Jessel

Prerequisites / notice
none

Neural Computation and Theoretical Neurosciences

227-1037-00L Introduction to Neuroinformatics W 6 credits 2V+1U+1A V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens

Abstract
The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

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Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monodisciplines of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

227-0421-00L Deep Learning in Artificial and Biological Neuronal Networks W 4 credits 3G B. Grewe

Abstract
Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn

real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.

Objective
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

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- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.
Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al. 2015, Silver et al., 2018), ANNs are still not performing on par when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples; they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

Lecture notes

The lecture slides will be provided as a PDF after each lecture.

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Neurotechnologies and Neuromorphic Engineering

<table>
<thead>
<tr>
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<th>Hours</th>
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<tbody>
<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6 credits</td>
<td>2+1U+1A</td>
<td>V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens</td>
</tr>
<tr>
<td>227-1033-00L</td>
<td>Neuromorphic Engineering I</td>
<td>W</td>
<td>6 credits</td>
<td>2+3U</td>
<td>T. Delbrück, G. Indiveri, S.-C. Liu</td>
</tr>
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Abstract

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

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Content

This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons.

The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

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<tr>
<td>227-1039-10L</td>
<td>Bioelectronics and Biosensors</td>
<td>W</td>
<td>6 credits</td>
<td>2+U+2</td>
<td>J. Vörös, M. F. Yanik</td>
</tr>
</tbody>
</table>
Abstract
The course introduces the concepts of bioelectricity and biosensing. The sources and use of electrical fields and currents in the context of biological systems and problems are discussed. The fundamental challenges of measuring biological signals are introduced. The most important biosensing techniques and their physical concepts are introduced in a quantitative fashion.

Objective
During this course the students will:
- learn the basic concepts in biosensing and bioelectronics
- be able to solve typical problems in biosensing and bioelectronics
- learn about the remaining challenges in this field

Content
L1. Bioelectronics history, its applications and overview of the field
- Volta and Galvani dispute
- BMI, pacemaker, cochlear implant, retinal implant, limb replacement devices
- Fundamentals of biosensing
- Glucometer and ELISA

L2. Fundamentals of quantum and classical noise in measuring biological signals

L3. Biomeasurement techniques with photons

L4. Acoustics sensors
- Differential equation for quartz crystal resonance
- Acoustic sensors and their applications

L5. Engineering principles of optical probes for measuring and manipulating molecular and cellular processes

L6. Optical biosensors
- Differential equation for optical waveguides
- Optical sensors and their applications
- Plasmonic sensing

L7. Basic notions of molecular adsorption and electron transfer
- Quantum mechanics: Schrödinger equation energy levels from H atom to crystals, energy bands
- Electron transfer: Marcus theory, Gerischer theory

L8. Potentiometric sensors
- Fundamentals of the electrochemical cell at equilibrium (Nernst equation)
- Principles of operation of ion-selective electrodes

L9. Amperometric sensors and bioelectric potentials
- Fundamentals of the electrochemical cell with an applied overpotential to generate a faraday current
- Principles of operation of amperometric sensors
- Ion flow through a membrane (Fick equation, Nernst equation, Donnan equilibrium, Goldman equation)

L10. Channels, amplification, signal gating, and patch clamp Y4

L11. Action potentials and impulse propagation

L12. Functional electric stimulation and recording
- MEA and CMOS based recording
- Applying potential in liquid - simulation of fields and relevance to electric stimulation

L13. Neural networks memory and learning

Literature
Plonsey and Barr, Bioelectricity: A Quantitative Approach (Third edition)

Prerequisites / notice
The course requires an open attitude to the interdisciplinary approach of bioelectronics.
In addition, it requires undergraduate entry-level familiarity with electric & magnetic fields/forces, resistors, capacitors, electric circuits, differential equations, calculus, probability calculus, Fourier transformation & frequency domain, lenses / light propagation / refractive index, Michaelis-Menten equation, pressure, diffusion AND basic knowledge of biology and chemistry (e.g. understanding the concepts of concentration, valence, reactants-products, etc.).

► Electives

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<tr>
<td>401-0151-00L</td>
<td>Linear Algebra</td>
<td>W</td>
<td>5 credits</td>
<td>3V+2U</td>
<td>V. C. Gradinaru</td>
</tr>
<tr>
<td>401-0603-00L</td>
<td>Stochastics (Probability and Statistics)</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>P. Cheridito</td>
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</table>

Objective
Einführung in die Lineare Algebra für Ingenieure unter Berücksichtigung numerischer Aspekte
K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002

Lecture notes

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

Objective
The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

Introduction to Computational Physics

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and supercomputers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Objective
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

Content
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes
Lecture notes and slides are available online and will be distributed if desired.

Electron Microscopy in Material Science

A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Objective
A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Content
This course provides a general introduction into electron microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, recent applications in materials science, solid state physics, structural biology, structural geology and chemical structure will be reported.

Lecture notes
Lecture notes will be distributed in English

Medical Physics I

Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

Objective
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society.

Content
The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the exercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

Lecture notes
A script will be provided.

Consciousness: From Philosophy to Neuroscience

This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained. Emphasis is placed on students developing their own thinking through a discussion-centered course structure.

Objective
The course's goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

Content
The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness, and proposals for the neural correlate of consciousness (NCC).

Lecture notes
None

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INV410

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmmss/en/studies/application/deadline.shtml

Abstract
This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained. Emphasis is placed on students developing their own thinking through a discussion-centered course structure.

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Content
The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness, and proposals for the neural correlate of consciousness (NCC).

Lecture notes
None

Literature
We display articles pertaining to the issues we cover in the class on the course's webpage.
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

**Fundamentals:**
- What is data?
- Bayesian Learning
- Computational learning theory

**Supervised learning:**
- Ensembles: Bagging and Boosting
- Max Margin methods
- Neural networks

**Unsupervised learning:**
- Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

**Lecture notes**
No lecture notes, but slides will be made available on the course webpage.

**Literature**

**Prerequisites / notice**
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

**GESS Science in Perspective**
- see GESS Science in Perspective: Language Courses
- ETH/UZH
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability
- Recommended GESS Science in Perspective (Type B) for D-ITET

**Master’s Thesis and Semester Papers/Seminars**

**Option 1: Long Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1041-01L</td>
<td>NSC Master’s Thesis (long) and Exam (University of Zurich)</td>
<td>W</td>
<td>45 credits</td>
<td>96D</td>
<td>R. Hahnloser</td>
</tr>
</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI503

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Only students who fulfill the following criteria are allowed to begin with their master thesis:
- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract
The Master thesis concludes the study programme. Thesis work should prove the students’ ability to independent, structured and scientific working.

Objective
see above

**Option 2: Short Master’s Thesis and Semester Papers/Seminars**

**Short Master Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1041-02L</td>
<td>NSC Master’s Thesis (short) and Exam (University of Zurich)</td>
<td>W</td>
<td>29 credits</td>
<td>62D</td>
<td>R. Hahnloser</td>
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</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI504

Only students who fulfill the following criteria are allowed to begin with their master thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract
The Master thesis concludes the study programme. Thesis work should prove the students’ ability to independent, structured and scientific working.

Objective
see above

Semester Papers/Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1036-01L</td>
<td>NSC Master Short Project I (University of Zurich)</td>
<td>W</td>
<td>8</td>
<td>17A</td>
<td>R. Hahnloser</td>
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<tr>
<td></td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: INI505</td>
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<td>Usually a student selects the topic of a Master Short Project in consultation with his or her mentor.</td>
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<tr>
<td>227-1036-02L</td>
<td>NSC Master Short Project II (University of Zurich)</td>
<td>W</td>
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<td></td>
<td>Objective</td>
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</tbody>
</table>

Neural Systems and Computation Master - Key for Type

| O          | Compulsory                                      | E-   | Recommended, not eligible for credits |
| W+         | Eligible for credits and recommended            | Z    | Courses outside the curriculum        |
| W          | Eligible for credits                            | Dr   | Suitable for doctorate                |

Key for Hours

| V          | lecture                                        | P    | practical/laboratory course           |
| G          | lecture with exercise                          | A    | independent project                   |
| U          | exercise                                       | D    | diploma thesis                        |
| S          | seminar                                        | R    | revision course / private study       |
| K          | colloquium                                     |      |                                        |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
## Core Courses

### 1. Semester (EPFL)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-2011-00L</td>
<td>Physics of Nuclear Reactors (EPFL)</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>external organisers</td>
</tr>
</tbody>
</table>

*Abstract*  
In this course, one acquires an understanding of the basic neutronics interactions occurring in a nuclear fission reactor and, as such, the conditions for establishing and controlling a nuclear chain reaction.

*Objective*  
By the end of the course, the student must be able to:  
- Elaborate on neutron diffusion equation  
- Systematize nuclear reaction cross sections  
- Formulate approximations to solving the diffusion equation for simple systems

*Content*  
- Brief review of nuclear physics  

*Literature*  
Distributed documents, recommended book chapters

*Prerequisites / notice*  
Prerequisite for: Reactor Experiments

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-2013-00L</td>
<td>Radiation and Reactor Experiments (EPFL)</td>
<td>O</td>
<td>4</td>
<td>5G</td>
<td>external organisers</td>
</tr>
</tbody>
</table>

*Abstract*  
To gain hands-on experience in the conduction of nuclear radiation measurements, as also in the execution and analysis of reactor physics experiments using the CROCUS reactor.

*Objective*  
To gain hands-on experience in the conduction of nuclear radiation measurements, as also in the execution and analysis of reactor physics experiments using the CROCUS reactor.

*Content*  
- Radiation detector systems, alpha and beta particles - Radiation detector systems, gamma spectroscopy - Introduction to neutron detectors (He-3, BF3) - Slowing-down area (Fermi age) of Pu-Be neutrons in H2O - Approach-to-critical experiments - Buckling measurements - Reactor power calibration - Control rod calibration

*Literature*  
Distributed documents, recommended book chapters

*Prerequisites / notice*  
Prerequisite for: Special Topics in Reactor Physics (2nd sem.)

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-2015-00L</td>
<td>Reactor Technology (EPFL)</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>A. Manera, external organisers</td>
</tr>
</tbody>
</table>

*Abstract*  
Basic heat removal phenomena in a reactor core, limits for heat generation and technological consequences arising from fuel, cladding and coolant properties, main principles of reactor thermal design, as well as the general design of the nuclear power plant with its main and auxiliary systems are explained. The system technology of the most important thermal and fast reactor types is introduced.

*Objective*  
By the end of the course, the student must be able to: (1) Understand design principles of nuclear reactors, (2) Understand purpose and function of main reactor and power plant components and subsystems, (3) assess and evaluate the performance of reactor types, (4) systematize reactor system components, (5) formulate safety requirements for reactor systems
By the end of the course, the student must be able to:

- Explain the basic physics principles that underpin radiotherapy, e.g. types of radiation, atomic structure, etc.
- Explain the interaction mechanisms of ionizing radiation at keV and MeV energies with matter.
- Explain the principles of radiation dosimetry.
- Explain the principles of therapeutic radiation physics including X-rays, electron beam physics, radioactive sources, use of unsealed sources and Brachytherapy.
- Describe how to use radiotherapy equipment both for tumour localisation, planning and treatment.
- Define quality assurance and quality control, in the context of radiotherapy and the legal requirements.
- Explain the principles and practice of radiation protection, dose limits, screening and protection mechanisms.
- Explain the use of radiation in industrial and research applications.

## Content

- Fuel rod, LWR fuel elements
- Temperature field in fuel rod
- Reactor core, design
- Flux and heat source distribution, cooling channel
- Single-phase convective heat transfer, axial temperature profiles
- Boiling crisis and DNB ratio
- Pressurized water reactors, design
- Primary circuit design
- Steam generator heat transfer, steam generator types
- Boiling water reactors
- Reactor design
- LWR power plant technology, main and auxiliary systems
- Breeding and transmutation, purpose of generation IV systems
- Properties of different coolants and technological consequences
- Introduction into gas-cooled reactors, heavy water moderated reactors, sodium and led cooled fast reactors, molten salt reactors, accelerator driven systems

## Literature

- Distributed documents, recommended book chapters
- Required prior knowledge: Neutronics
- Prerequisite for: Nuclear Safety (2nd sem.)

### 151-2043-00L Radiation Biology, Protection and Applications (EPFL) O

**No enrolment to this course at ETH Zurich. Book the corresponding module directly at EPFL.**

**Abstract**

An introductory course in the basic concepts of radiation detection and interactions and energy deposition by ionizing radiation in matter, radioisotope production and its applications in medicine, industry and research. The course includes presentations, lecture notes, problem sets and seminars.

**Objective**

- Explain the basic physics principles that underpin radiotherapy, e.g. types of radiation, atomic structure, etc.
- Explain the interaction mechanisms of ionizing radiation at keV and MeV energies with matter.
- Explain the principles of radiation dosimetry.
- Explain the principles of therapeutic radiation physics including X-rays, electron beam physics, radioactive sources, use of unsealed sources and Brachytherapy.
- Describe how to use radiotherapy equipment both for tumour localisation, planning and treatment.
- Define quality assurance and quality control, in the context of radiotherapy and the legal requirements.
- Explain the principles and practice of radiation protection, dose limits, screening and protection mechanisms.
- Explain the use of radiation in industrial and research applications.

### Content

Basics: radiation sources and interaction with matter, radioisotope production using reactors and accelerators, radiation protection and shielding.

Medical applications: diagnostic tools, radiopharmaceuticals, cancer treatment methodologies such as brachytherapy, neutron capture therapy and proton therapy.

Industrial applications: radiation gauges, radiochemistry, tracer techniques, radioisotope batteries, sterilization, etc.

Applications in research: dating by nuclear methods, applications in environmental and life sciences, etc.

## Literature

- Notes de cours polycopiées et littérature spécialisée (IMHEF, industrie, associations scientifiques, congrés, etc.).

## Prerequisites / notice

- Prérequis: Mécanique des milieux continus; Introduction aux turbomachines.
- Préparation pour: Choix des équipements hydrauliques; Projets et travail pratique de Master.
### Nuclear Fusion and Plasma Physics (EPFL)

**Course Code:** 151-2023-00L  
**Credits:** 4  
**Objective:**  
- Design the main elements of a fusion reactor  
- Identify the main physics challenges on the way to fusion  
- Identify the main technological challenges of fusion  

**Content:**  
1. Basics of thermonuclear fusion  
2. The plasma state and its collective effects  
3. Charged particle motion and collisional effects  
4. Fluid description of a plasma  
5. Plasma equilibrium and stability  
6. Magnetic confinement: Tokamak and Stellarator  
7. Waves in plasma  
8. Wave-particle interactions  
9. Heating and non inductive current drive by radio frequency waves  
10. Heating and non inductive current drive by neutral particle beams  
11. Material science and technology: Low and high Temperature superconductor - Properties of material under irradiation  
12. Some nuclear aspects of a fusion reactor: Tritium production  
13. Licensing a fusion reactor: safety, nuclear waste  
14. Inertial confinement  

**Literature:**  

**Prerequisites / notice:**  
Required prior knowledge:  
- Basic knowledge of electricity and magnetism, and of simple concepts of fluids

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### Introduction to Particle Accelerators (EPFL)

**Course Code:** 151-2025-00L  
**Credits:** 4  
**Objective:**  
- Design basic linear and non-linear charged particles optics  
- Elaborate basic ideas of physics of accelerators  
- Use a computer code for optics design  
- Optimize accelerator design for a given application  
- Estimate main beam parameters of a given accelerator  

**Content:**  
- Overview, history and fundamentals  
- Transverse particle dynamics (linear and nonlinear)  
- Longitudinal particle dynamics  
- Linear accelerators  
- Circular accelerators  
- Acceleration and RF-technology  
- Beam diagnostics  
- Accelerator magnets  
- Injection and extraction systems  
- Synchrotron radiation  

**Literature:**  
Recommended during the course  

**Prerequisites / notice:**  
- Prérequis: Notion de relativité restreinte et d'électrodynamique

---

### Introduction to Medical Radiation Physics (EPFL)

**Course Code:** 151-2041-00L  
**Credits:** 4  
**Objective:**  
The focus is not only on risk and dose to the patient and staff, but also on an objective description of the image quality.  

**Content:**  
- Physics of radiography: X-ray production, Radiation-patient interaction, Image detection and display  
- Image quality: Wagner's taxonomy, MTF, NPS, contrast, SNR, DQE, NEQ, CNR  
- Dose to the patient: External irradiation, Internal contamination, compartmental models  
- Physics of computer tomography (CT)  
- Risk and radiation: Rational risk and state of our knowledge, Psychological aspects, Ethics and communication  
- Physics of single-photon emission computed tomography (SPECT)  
- Physics of mammography  
- Receiver operating characteristics (ROC) and hypothesis testing: Link between medical diagnostic and statistical hypothesis testing, Sensitivity, specificity, prevalence, predictive values  
- Physics of radioscopy  
- Model observers in medical imaging: Human visual characteristics and their quantification, Bayesian cost and Ideal model observer, Anthropomorphic model observers, Detection experiments (rating, M-AFC, yes-no)  
- Physics of positron emission tomography (PET)  
- Physics of resonance magnetic imaging  

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### Physics of Atoms, Nuclei and Elementary Particles (EPFL)

**Course Code:** 151-2047-00L  
**Credits:** 4  

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**Data:** 14.12.2021 12:41  
**Autumn Semester 2021**  
**Page:** 1654 of 2152
The elective project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. The subject of the Elective Project and the choice of the supervisor (ETH or EPFL professor) are to be approved in advance by the tutor.

The elective project has the purpose to train the students in the solution of specific engineering problems related to nuclear technology. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

The elective project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

### Literature

Radiation detection and measurement, Glenn F. Knoll. Wiley 2010


### Content

- Advanced Topics in Nuclear Reactor Materials
  - Students registered at ETH Zurich have to enroll to this course at ETH. EPFL students can enroll to this course
  
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>151-0150-00L</td>
<td>Advanced Topics in Nuclear Reactor Materials</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>M. A. Pouchon, P. J.-P. Spätig, M. Streit</td>
</tr>
</tbody>
</table>

### Prerequisites / notice

- Required courses: Quantum mechanics, electrodynamics and special relativity

### Objective

- Important concepts to start the course: Symmetry and conservation, lorentz invariance and spin and statistics
The course deals with the important challenges for materials (structural and fuel) for current and advanced nuclear power plants. Experimental techniques and tools used for working with active materials are discussed in detail. Students will be well acquainted with analytical and modeling methodologies for damage assessment and residual life determination and with the behavior of high burnup fuel.

Objective

The behaviour of materials in nuclear reactors determines the reliability and safety of nuclear power plants (NPPs). Life extension and the understanding of fuel behavior under high burn-up conditions is of central importance for current-day NPPs. Advanced future systems (fission and fusion) need materials meeting additional challenges such as high temperatures and/or high doses. The course will highlight the above needs from different points of view. Experimental methods for the control and analysis of nuclear components and materials in operating NPPs will be presented. Advanced analytical and modeling tools will be introduced for characterization and understanding of irradiation damage, creep, environment effects, etc. Insights acquired from recent experimental programs into high burnup fuel behavior under hypothetical accident conditions (RIA, LOCA) will be presented. Materials for advanced future nuclear plants will be discussed.

151-2037-00L Nuclear Computations Lab

**Objective**

To acquire hands-on experience with the running of large computer codes in relation to the static analysis of nuclear reactor cores and the multi-physics simulation of nuclear power plant (NPP) dynamic behaviour.

**Content**

- Lattice (assembly) calculations
- Thermal-hydraulic analysis
- Reactor core analysis
- Multi-physics core dynamics calculations
- Best-estimate NPP transient analysis

**Lecture notes / Prerequisites / notice**

Hand-outs will be distributed. Required prior knowledge: Special Topics in Reactor Physics, Nuclear Safety

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151-2039-00L Beyond-Design-Basis Safety

**Abstract**

Comprehensive knowledge is provided on the phenomena during a Beyond Design Bases Accident (BDBA) in a Nuclear Power Plant (NPP), on their modeling as well as on countermeasures taken against radioactive releases into the environment, both by Severe Accident Management Guidelines (SAMG), together with technical backfilling measures in existing plants and an extended design of new NPP.

**Objective**

Deep understanding of the processes associated with core degradation and fuel melting in case of sustained lack of Core Cooling Systems, potential threats to the containment integrity, release and transport of active and inactive materials, the function of the containment, containment, countermeasures mitigating release of radioactive material into the environment (accident management measures, back-filling and extended design), assessment of timing and amounts of released radioactive material (source term measures).

**Content**

Physical basic understanding of severe accident phenomenology: loss of core cooling, core dryout, fuel heat-up, fuel rod cladding oxidation and hydrogen production, loss of core coolability and, fuel melting, melt relocation and melt accumulation in the lower plenum of the reactor pressure vessel (RPV), accident evolution at high and low reactor coolant system pressure, heat flux from the molten debris in the lower plenum and its distribution to the lower head, RPV failure and melt ejection, direct containment heating, molten corium and concrete interaction, in- and ex-vessel molten fuel coolant interaction (steam explosions), hydrogen distribution in the containment, containment risk (deflagration, transition to detonation), pressure buildup and containment vulnerability, countermeasures mitigating/avoiding hydrogen deflagration, formation, transport and deposition of radioactive aerosols, iodine behavior, plant ventilation filtration systems, filtered venting to avoid containment failure and mitigate activity release into the environment, containment bypass scenarios, source term assessment, in-vessel and ex-vessel corium retention, behavior of fuel elements in the spent fuel pool during long-lasting station blackout, cladding oxidation in air, discussion of occurred severe accidents (Harrsiburg, Chernobyl, Fukushima), internal and external emergency response. Probabilistic assessment and interfacing with severe accident phenomenology.

**Lecture notes / Prerequisites / notice**

Hand-outs will be distributed. Prerequisite courses: 151-0156-00L Safety of Nuclear Power Plants plus either 151-0163-00L Nuclear Energy Conversion or 151-2015-00L Reactor Technology

---

151-2045-00L Decommissioning of Nuclear Power Plants

**Abstract**

Introduction to aspects of Nuclear Power Plant decommissioning including project planning and management, costs and financing, radiological characterization, dismantling/decontamination technologies, safety aspects and radioactive waste management considerations.

**Objective**

The course is designed to provide students with an overview of the multidisciplinary issues that have to be addressed for the successful decommissioning of NPPs. Students will get exposed to principles of project management, operations management, cost estimations, radiological characterization, technologies relevant to the safe dismantling of NPPs and best-practice in the context of radioactive waste management.

**Content**

Legal framework, project management and operations methods and tools, cost estimation approaches and methods, nuclear calculations and on-site radiological characterization and inventorying, state-of-the-art technologies for decontamination and dismantling, safety considerations, state-of-the-art practice for radioactive waste treatment, packaging and transport, interface with radioactive waste management and disposal. The course will additionally include student visits to relevant nuclear sites in Switzerland and Germany.

**Lecture notes / Literature**

Slides will be handed out.

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151-2005-00L Elective Project Nuclear Engineering

**Objective**

The elective project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

**Prerequisites / notice**

Recommended courses: Nuclear Energy Conversion or 151-2015-00L Reactor Technology

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### 227-0385-10L Biomedical Imaging

**Objective**
To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

**Content**
- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Literature**
Webb A, Smith N.B. Introduction to Medical Imaging: Physics, Engineering and Clinical Applications; Cambridge University Press 2011

**Prerequisites / notice**
Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

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### 227-0965-00L Micro and Nano-Tomography of Biological Tissues

**Abstract**
The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphometry and statistics.

**Objective**
Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications

**Content**
Synchronotron-based X-ray micro- and nano-tomography is today a powerful technique for non-destructive, high-resolution investigations of a broad range of materials. The high-brilliance and high-coherence of third generation synchrotron radiation facilities allow quantitative, three-dimensional imaging at the micro and nanometer scale and extend the traditional absorption imaging technique to edge-enhanced and phase-sensitive measurements, which are particularly suited for investigating biological samples.

The lecture includes a general introduction to the principles of tomographic imaging from image formation to image reconstruction. It provides the physical and engineering basics to understand how imaging beamlines at synchrotron facilities work, looks into the recently developed phase contrast methods, and explores the first applications of X-ray nano-tomographic experiments.

The course finally provides the necessary background to understand the quantitative evaluation of tomographic data, from basic image analysis to complex morphometrical computations and 3D visualization, keeping the focus on biomedical applications.

**Lecture notes**
Available online

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### Electives

Course from the catalogue of Master courses ETH Zurich and EPFL. At least 4 credit points must be collected from the offer of Science in Perspective (SIP) compulsory electives at ETH Zurich or Management of Technology and Entrepreneurship at EPFL.

### Industrial Internship

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<td>Industrial Internship</td>
<td>O</td>
<td>8 credits</td>
<td>external organisers</td>
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</table>

**Abstract**
The main objective of the minimum twelve-week internship is to expose Master’s students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

**Objective**
The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

### Semester Project

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<tr>
<td>151-1020-00L</td>
<td>Semester Project Nuclear Engineering</td>
<td>O</td>
<td>8 credits</td>
<td>Professors</td>
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</tbody>
</table>

The subject of the Semester Project and the choice of the supervisor (ETH or EPFL professor) are to be approved in advance by the tutor.

**Abstract**
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

**Objective**
The aim of the Semester Project is to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's programme.

---

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1009-00L</td>
<td>Master's Thesis Nuclear Engineering</td>
<td>O</td>
<td>30 credits</td>
<td>Supervisors</td>
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</tr>
</tbody>
</table>

Students who fulfill the following criteria are allowed to begin with their Master's Thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.
c. successful completion of the semester project.
d. completion of minimum 72 ECTS in the categories "Core Courses" and "Electives" in the Master studies and completion of 8 ECTS in the "Semester Project"

For the supervision of the Master's Thesis, the following professors can be chosen: H.-M. Prasser (ETHZ), A. Prussmann.
Abstract
Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Objective
The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

Nuclear Engineering Master - Key for Type

<table>
<thead>
<tr>
<th>Key</th>
<th>Type</th>
<th>Notes</th>
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<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td></td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td></td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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</table>

Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
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</table>

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Pharmaceutical Sciences Master

Core Courses I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0030-00L</td>
<td>Therapeutic Proteins</td>
<td>O</td>
<td>3</td>
<td>3G</td>
<td>C. Hain Winter, D. Neri</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>Students know and understand:</td>
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<tr>
<td></td>
<td>- basic mechanisms and regulation of the immune response</td>
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<td></td>
<td>- the pathogenic mechanisms of the most important immune-mediated disorders</td>
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<td></td>
<td>- the most frequently used expression systems for the production of therapeutic proteins</td>
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<td></td>
<td>- the use of protein engineering tools for modifying different features of therapeutic proteins</td>
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<td></td>
<td>- the mechanism of action of selected therapeutic proteins and their application</td>
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<td></td>
<td>- basic concepts in the GMP production of therapeutic proteins</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>The course consists of two parts:</td>
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<td></td>
<td>In a first part, students will complete their training of pharmaceutical immunology (Chapter 13 - 16 Immunobiology VIII textbook). This part particularly focuses on the pathogenic mechanisms of immune-mediated diseases. Deepened knowledge of immunology will be relevant for understanding the mechanism of action of many therapeutic proteins, as well as for understanding one major concern related to the use of protein-based drugs, namely, immunogenicity.</td>
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<td>The second part focuses on topics related to the development and application of therapeutic proteins, such as protein expression, protein engineering, reducing immunogenicity, and GMP production of therapeutic proteins. Furthermore, selected examples of approved therapeutic proteins will be discussed.</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<tr>
<td></td>
<td>Handouts to the lectures will be available for downloading under <a href="http://www.pharma.ethz.ch/scripts/index">http://www.pharma.ethz.ch/scripts/index</a></td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>- Janeway's Immunobiology, by Kenneth Murphy (9th Edition), Chapters 12-16</td>
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<tr>
<td></td>
<td>- Lecture Handouts</td>
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<tr>
<td></td>
<td>- Paper References provided in the Scripts</td>
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<td>- EMEA Dossier for Humira</td>
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<tr>
<td>535-0041-00L</td>
<td>Pharmacology and Toxicology III</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>M. Detmar, U. Quitterer</td>
</tr>
<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The course is divided into two parts. The first part provides a detailed understanding of drugs and pharmacotherapy of infectious diseases and cancer. The second part gives an overview of the field of pharmacogenomics with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.</td>
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<tr>
<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases and cancer. The course also provides an overview of the field of pharmacogenomics, with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<td></td>
<td>Topics include the pharmacology and pharmacotherapy of infectious diseases and cancer. In the field of pharmacogenomics, the course is focused on genetics, genome-wide association studies, genetic disease predisposition, examples of genetic variability of drug metabolism and drug responses, identification of new drug targets, relevance of pharmacogenomics for clinical drug development, and toxicogenomics.</td>
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<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>A script is provided for each lecture course. The scripts define important and exam-relevant contents of lectures. Scripts do not replace the lecture.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<td>Recommended reading:</td>
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<td></td>
<td>The classic textbook in Pharmacology:</td>
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<td></td>
<td>Goodman and Gilman’s The Pharmacological Basis of Therapeutics</td>
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<tr>
<td></td>
<td>Lawrence Brunton, Bjorn Knollman, Randa Hilal-Dandar.</td>
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<td></td>
<td>ISBN-10: 1259584739</td>
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<td>or</td>
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<td></td>
<td>Klaus Aktories, Ulrich Förstermann, Franz Hofmann, Klaus Starke.</td>
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<tr>
<td></td>
<td>Allgemeine und spezielle Pharmakologie und Toxikologie.</td>
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<tr>
<td>535-0050-00L</td>
<td>Pharmacaeopidemiology and Drug Safety</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>A. Burden, S. Russmann</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>Introduction to the principles, methods and applications of pharmacoepidemiology and drug safety. Drug safety in the pharmaceutical industry and regulatory authorities, but also for hospital and office pharmacists. Another focus is the evaluation and interpretation of pharmacoepidemiological drug safety studies in the medical literature and the evaluation of benefits vs. risks.</td>
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<td><strong>Objective</strong></td>
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<td>Objectives:</td>
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<td></td>
<td>- To familiarize participants with the principle methods and applications of pharmacoepidemiology and drug safety that is relevant for industry, regulatory affairs, but also for clinical pharmacists in hospitals and office pharmacies.</td>
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<td>- Perform independently a causality assessment of suspected adverse drug reactions in patients</td>
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<td></td>
<td>- Study designs and biostatistics used for the quantitative evaluation of drug safety</td>
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<td></td>
<td>- Setup of programs that can effectively reduce medication errors and improve drug safety in clinical practice, particularly in hospitals</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>- Historical landmarks of drug safety</td>
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<td></td>
<td>- Pharmacovigilance and causality assessment</td>
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<td>- Drug safety in premarketing clinical trials</td>
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<td></td>
<td>- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding</td>
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<td></td>
<td>- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPs)</td>
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<td></td>
<td>- Medication errors, clinical pharmacology / clinical pharmacy</td>
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<td></td>
<td>- Clinical Decision Support Systems, Interventional Pharmacoepidemiology</td>
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<td></td>
<td>- Pharmacoepidemiological databases, ‘Big Data’</td>
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<tr>
<td></td>
<td>- Interactive discussion of many real-life examples for each topic</td>
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<tr>
<td></td>
<td><strong>Lecture notes</strong></td>
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<td></td>
<td>This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups. Reading material and scripts will be provided for each week.</td>
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<tr>
<td></td>
<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>Recommended literature</td>
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<tr>
<td></td>
<td>- Rothman: Introduction to Epidemiology</td>
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<td></td>
<td>- Strom, Kimmel, Hanneisy: Textbook of Pharmacoepidemiology</td>
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<td></td>
<td>- Gigenerzen: Risk Savvy - How to Make Good Decisions</td>
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</tbody>
</table>
### Concepts and Theories

**Analytical Competencies** not assessed


**Communication** assessed

The class enables the participants to prepare their own scientific texts and oral presentations, and critically assess the quality of published scientific works in the field of intellectual property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.

**2 credits**

### Drug Discovery and Development

**535-0546-00L**

**O** 1 credit 1V A. Koepf, P. Pliska

**Abstract**

Knowledge in the field of intellectual property, especially of patents and trademarks, with particular emphasis on pharmaceutics.

**Objective**

Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.

**Content**

1. Introduction into industrial property (patents, trademarks, industrial designs);
2. Prosecution of patent applications (patentability);
3. Patent information (patent publications, databases, searches);
4. Exploitation and enforcement of patents (possibilities of exploitation, licenses, parallel imports, scope of protection, patent infringement);
5. Peculiarities in pharmaceutics and medicine (supplementary protection certificates, experimental use exemption, therapy and diagnosis, medical indication);
6. Social, political and ethical aspects (patents and prices for medicinal products, traditional knowledge and ethnomedicine, bioprospecting and biopiracy, human DNA inventions);
7. Trademarks, types of trademarks, grounds for refusal, peculiarities of pharma-trademarks.

**Lecture notes**

A script is provided in electronic form during the lecture.

**Literature**


**Prerequisites / notice**

None

---

### Scientific Writing and Presenting

**535-0546-00L**

**O** 2 credits 1G+1S J. A. Hiss

**Abstract**

This introductory class provides an overview of the basic scientific writing techniques and a guideline to presenting scientific data, together with guided exercises and hands-on training. It is devised to accompany the research projects within the curriculum of the MSc in Pharmaceutical Sciences.

**Objective**

The class enables the participants to prepare their own scientific texts and oral presentations, and critically assess the quality of the presentation of scientific data.

**Prerequisites / notice**

None

---

### Drug Discovery and Development

**511-0000-00L**

**O** 2 credits 1G+1S J. Hall, U. Thibaut, K.-H. Altmann, M. Arand, J. Scheuermann, R. Schibli, H. U. Zeilhofer

**Abstract**

This course provides an overview over the concepts and processes employed in today's drug discovery and development. It has an introductory character but will also provide more detailed insights employing real life examples. The course combines lectures and interactive elements with active participation of the students.

**Objective**

Students
- Understand the drug discovery process and can explain major approaches and relevant technical terms (for details see lecture notes).
- Understand and appreciate the content and timing of drug development process steps, development phases and decision criteria.
- Understand the concepts underlying drug product development through all the phases from preclinical and clinical development to regulatory submission, approval and market launch.
- Can differentiate between small molecule drug development and biological drug development.
- Understand the most important differences between legal and regulatory requirements for drug development and approval for the major markets EU and USA.

**Content**

Course unit comprises weekly lectures covering the early phases of target and drug discovery (535-0901-01 S "From A to Z in Drug Discovery and Development") with group work in the area of Drug Development (511-0000-00 G). Group work is 2 full days (Days 1 and 2) and comprises: introduction to the entire suite of drug product development processes in the pharmaceutical industry, covering: preclinical research and development, clinical development, regulatory processes and market launch. R&D support processes such as project management, quality management, pharmacovigilance and pharmacoconomics will be covered as well as organizational and governance aspects of the pharmaceutical industry. In addition, important success factors for a later career in the pharmaceutical industry will be discussed and highlighted at the end of the course.

**Lecture notes**

Will be published on “mystudies”

**Literature**


Further readings will be listed in the lecture notes.

**Prerequisites / notice**

This course provides the essential basic knowledge required for the industry-specific modules of the spring semester.

Safety concept: [https://chab.ethz.ch/studium/bachelor1.html](https://chab.ethz.ch/studium/bachelor1.html)
### Electives I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

#### Content

The participants receive an introduction to basic formal aspects of scientific writing and the design of graphical elements. Lectures and topical seminars alternate with practical task for the participants, which will be evaluated in a peer-to-peer setting. Performance feedback is provided by both the teachers and the peers.

#### Electives I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

#### Abstract

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences. Students work in small groups on a chosen topic, they write a mini-review and present their work on a one day symposium.

#### Objective

The main objectives of this course are:

- students develop their scientific reflection (Critical Thinking) and working skills by working independently on a relevant pharmaceutical topic
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing and presentation skills
- students train their ability to plan a project and work in a team

#### Content

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences.

During the course, students work in small teams on a topic of their choice and elaborate a written mini-review and oral presentation. Each team is tutored by a lecturer of the Institute of Pharmaceutical Sciences. The work is mainly based on literature search / review, but may also involve conducting interviews or site visits, if appropriate. The final presentations of all groups will take place in the framework of a dedicated Symposium held in the middle of the semester.

#### Prerequisites / notice

Only for students of MSc Pharmacy and MSc Pharmaceutical Sciences.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>511-1001-00L</td>
<td>Biopharmacy (Crash Course)</td>
<td>E</td>
<td>2 credits</td>
<td>1S</td>
<td>S.-D. Krämer</td>
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</tbody>
</table>

#### Content

- Knowledge of the ADMET processes and the respective pharmacokinetic parameters.
- Interpretation of pharmacokinetic parameters.
- Analysis of drug plasma concentration-time curves.
- Prediction of pharmacokinetic parameters based on in vitro assays and physicochemical drug properties.
- Knowledge of the effects of physiological factors on the pharmacokinetic parameters and on drug plasma and tissue concentrations.
- Design of dosage regimens, based on pharmacokinetic parameters.
- Prediction of drug-drug interaction parameters based on in vitro assays and pharmacokinetic parameters.

#### Literature


DOI: 10.1002/9783527645763


#### Prerequisites / notice

Only for Pharmaceutical Sciences MSc.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>511-1002-00L</td>
<td>Pharmaceutical Analytics and Pharmacopeia (Crash Course)</td>
<td>E</td>
<td>2 credits</td>
<td>1S</td>
<td>C. Steuer</td>
</tr>
</tbody>
</table>

#### Content

- students train their ability to plan a project and work in a team
- students gain knowledge in pharmaceutical analytics to fulfill regulatory requirements in pharmaceutical industry based on the pharmacoepia in force. Focus is set on method validation, equipment qualification, identification, purity testing and content determination of active pharmaceutical ingredients and excipients.

#### Literature

Adaptability and Flexibility

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, not assessed slides and script used for the course and literature for reading and discussions will be made available online.

Communication

The students remember and understand: W assessed W assessed W assessed

Analytical Competencies

The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This assessed course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

Drug Delivery and Drug Targeting

The students remember and understand:

1. The tools of recombinant DNA technology
2. Next generation sequencing approaches and their relevance for -omics projects
3. Protein cloning, expression, modification/labelling and oligomerization
4. Thermodynamic and kinetic affinity constants in bimolecular reactions
5. Basic structure of the antibody molecule
6. Concepts of antibody phage technology and antibody engineering
7. Construction of antibody-, peptide- or small molecule libraries and affinity-based selection methodologies

Content

1) Genomics:
- recombinant DNA technology
- methods to sequence genomes
- application to human biology
- Transcriptomics / Proteomics

2) Proteins:
- protein cloning and expression
- homo- and heterodimerization
- chemical modifications and radioactive labelling
- detection of bimolecular interactions
- affinity constant and experimental measurement
- kinetic association and dissociation constants

3) Display technology:
- the antibody molecule, CDRs, basics of antibody engineering
- antibody phage display and selection methodologies
- construction of antibody libraries
- other display technologies (peptide display, DNA-encoded chemical libraries)

Lecture notes

Slides and script used for the course and literature for reading and discussions will be made available online.

Literature

Dedicated chapters of:


Further references will be provided in the course.

Prerequisites / notice

Admission to MSc in Pharmaceutical Sciences

Biotransformation of Drugs and Xenobiotics

Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Related article will be announced.
Protein-based drugs constitute around 25% of new approvals and most of them are glycoproteins. Using selected examples of prominent glycoprotein drugs, the course aims at providing insight into glycosylation-activity relationships and into biotechnological production and analytics.

Students gain basic knowledge in "pharmaceutical glycobiology". This implies knowing and understanding:

- Major reactions of biotransformation.
- Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics.
- How glycoprotein drugs are produced (including the most important expression systems used), glycoengineered and analysed (quality control).
- The major types of protein-linked glycans and the biosynthetic pathways for their formation.
- Major mechanisms underlying the roles of glycosylation for the biological/therapeutic actions of glycoproteins (glycosylation-function relationships) using prominent examples of glycoprotein drugs.
- Traditional knowledge in relation to the fight against malaria and its implementation in research, product development and development cooperation. Introduction to and selected examples of herbal drugs and poisons, mode of action, and their ethnopharmacological importance. Critical analysis of bioprospecting as a drug discovery strategy.

Students are able to apply this knowledge in solving simple problems in glycoprotein drug development (on paper). Students gain the ability to reflect on roles of glycosylation in various biological contexts.
Communication assessed

On average one drug per year is withdrawn from the market. Using selected examples of such drug failures, the course aims at analyzing

Hand-outs will be distributed during the lecture (partly in English, partly in German).

Concepts and Theories

Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) Vitamins are essential organic compounds that cannot be synthesized by an organism and hence, they have to be acquired from the diet. 

lecture plan:

1. Glycans - information carriers in biology and pharmacotherapy
2. Glucocerebrosidase and the biosynthesis of N-glycans
3. Improving the therapeutic profile of monoclonal antibodies by glycoengineering
4. Mucin-type O-glycans and sialylation as gCQA of glycoprotein hormone drugs
5. production and gCQA analysis of Glucocerebrosidase, monoclonal antibodies, glycoprotein hormone drugs - Glycoanalytics
6. EPO "the same but different"

Abstract

On average one drug per year is withdrawn from the market. Using selected examples of such drug failures, the course aims at analyzing and discussing the present explanations of drug actions as well as the design and predictive power of animal models and clinical trials. In addition, the ethical, societal, and economical expectations in new drugs shall be reflected and discussed.

Objective

To develop a critical understanding of the relevance and limitations of the current approaches to explaining and anticipating drug effects.

To critically appraise the ethical, societal, economical and political expectations in the development of new drugs.

Content

In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and it's prevention by drug therapy. It has also highlighted what high expectations we have in a safe and wide applicability of drugs and of their economical success.

Torcetrapib is not a single case. In the last 10 years, on average one drug per year was withdrawn from the market due to lack of efficacy, unexpected side effects or toxicity. This clearly shows that the common investigations and the modern understanding of drug actions are often not sufficient to predict the effects a drug will have in large patient populations.

These are the topics of the present course. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

Lecture notes

Lecture slides and literature for reading and discussions will be available online.

Literature

- recent publications as cited/proposed on the lecture slides

Prerequisites / notice

Requirements: Basic knowledge in pharmacology, molecular biology, protein and carbohydrate chemistry, analytical techniques. Basic knowledge in pharmacology.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Problem-solving assessed

Domain C - Social Competencies
Communication assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

535-0300-00L Molecular Mechanisms of Drug Actions and Targets W 2 credits 1V J. Scheuermann

Number of participants limited to 24.

Abstract

On average one drug per year is withdrawn from the market. Using selected examples of such drug failures, the course aims at analyzing and discussing the present explanations of drug actions as well as the design and predictive power of animal models and clinical trials. In addition, the ethical, societal, and economical expectations in new drugs shall be reflected and discussed.

Objective

To develop a critical understanding of the relevance and limitations of the current approaches to explaining and anticipating drug effects.

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Content

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These are the topics of the present course. Using three particularly informative examples of drug failures, the problems encountered and the concepts and informative value of preclinical and clinical studies will be analyzed and discussed. Furthermore, the ethical, societal, economical and political expectations in new drugs shall be reflected.

Lecture notes

Lecture slides and literature for reading and discussions will be available online.

Prerequisites / notice

Requirements: Basic knowledge in Medicinal Chemistry and Pharmacology. Ability to read and understand scientific publications written in English.

535-0021-00L Vitamins in Health and Disease W 1 credit 1V C. Müller

Abstract

Vitamins are essential organic compounds that cannot be synthesized by an organism and hence, they have to be acquired from the diet. This lecture will give an overview about the application of vitamins in health and disease.

Objective

The aim of this lecture is a critical examination of the students with the topic of "Vitamins in Health and Disease". The students will get an overview of vitamins, of their medical applications and the role of the pharmacist with "over-the-counter" products.

Content

Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. However, these are exactly the cases where advice of a pharmacist is requested.

A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period.

The lecture 'Vitamins in Heath and Disease' will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.

Lecture notes

Hand-outs will be distributed during the lecture (partly in English, partly in German).

Literature

Book recommendation: reference books:

- Handbuch Nährstoffe, Burgerstein.
- Trias Verlag ISBN 978-3-8304-6071-8

Prerequisites / notice

Requirements: basic knowledge in Medicinal Chemistry and Pharmacology. Ability to read and understand scientific publications written in English.

535-0360-00L Evidence Based Phytotherapy W 1 credit 1V K. Berger Büter

Abstract

Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) Identification of drug candidates, b) registration requirements, c) criteria to assess efficacy, d) biomarkers and pharmacokinetics, e) safety and f) principles of extract generation. Important prototypes will be discussed.
### Objective
Students should learn the importance of rational (= evidence based) pharmacotherapy with herbal extracts:

- They should get to know the development process of herbal drugs:
  - How are interesting development candidates being identified? What are the strategies?
  - What are the regulatory requirements (traditional use, well-established use, new herbal entities)?
  - What are the selection criteria?
  - Assessment of efficacy (animal-/human studies, biomarker)
  - Pharmacokinetics
  - Safety (Toxicity, unwanted adverse effects, drug-drug interactions)
  - Pharmaceutical quality
  - Securing of herbal identity (collections, agriculture)
  - Quality management
  - selection of appropriate extraction procedures?
- Important prototy pes will be presented and critically discussed; see prgram below

### Content
**535-0137-00L**
**Clinical Chemistry II**
- W 1 credit 1V
- M. Hersberger

*Abstract*
Detailed knowledge on particular aspects of clinical chemistry and medical laboratory diagnostics concerning quality control, point-of-care analytics, analytics of kidney stones, tumor markers, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

*Objective*
Detailed knowledge on the implementation and interpretation of clinical laboratory diagnostic tests. Competence to interpret selected tests.

*Content*
Internal and external quality control, point-of-care analytics, analytics of kidney stones, use of tumor marker determinations, diagnosis of HIV and hepatitis, pharmacogenetics, thyroid function, bone metabolism and laboratory diagnosis of hypertension.

*Prerequisites / notice*
Requirement: basic knowledge in clinical chemistry and laboratory diagnostics

### Literature
- Jürgen Hallbach, *Klinische Chemie und Hämatologie für den Einstieg*, Thieme Verlag
- Harald Renz, *Praktische Labordiagnostik, de Gruyter Verlag*
- Walter Guder, *Das Laborbuch für Klinik und Praxis*, Elsevier Verlag
- Lothar Thomas, *Labor und Diagnose, TH Books*

### Praktische Labordiagnostik
**535-0022-00L**
**Computer-Assisted Drug Design**
- W 1 credit 1V
- S. Riniker, G. Landrum

*Abstract*
The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

*Objective*
The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

*Content*
The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.), and structure-based virtual screening (docking, physics-based models).

*Prerequisites / notice*
Recommended textbooks:

*Abstract*
The lecture is organized as a two-week block during the practical course "Computer-Assisted Drug Design" (535-0023-00 L), totalling 10 two-hour lectures. It provides an introduction to advanced drug design techniques and approaches emphasizing computer-assisted molecular design.

**Methods in Drug Design**
- W 1 credit 1V
- G. Schneider

*Abstract*
Does not take place this semester.

Complementary to the practical course "Computer-Assisted Drug Design (Practical Course)" 535-0023-00L.

Compulsory for the students of the practical course, open for other interested students.

The lecture will be presented along with the computer assisted course. The topics cover molecular structures, drug design concepts, and computer-aided drug design.

Script will be available.
Objective
Participants will learn about computational algorithms and advanced experimental approaches to drug discovery and design, including selected actual topics and practical applications. The contents of the lecture will allow for a deeper understanding of modern computer-assisted drug design methods and how they are linked to experimental applications. The main focus is on computational medicinal chemistry, so that participants will be able to use relevant computer-based methods in own research projects.

Literature

Prerequisites / notice
The lecture is mandatory for all participants of the course "Computer-Assisted Drug Design" (535-0023-00). Additional selected literature will be provided during the lecture.

535-0023-00L Computer-Assisted Drug Design (Practical Course) W 4 credits 6P G. Schneider

Abstract
The practical course is open for master and graduate students to get an introduction into hands-on computer-assisted drug design. The class includes an introduction to computer-based screening of a virtual compound library, subsequent synthesis of candidate ligands, and biochemically testing for activity on pharmacologically important drug targets.

Objective
Participants become familiar with state-of-the-art methodologies in a real-life computer-aided medicinal chemistry project. Participants work as small teams, perform literature research and discuss recent research findings. A seminar talk is to be given presenting the molecular design strategy chosen and the results obtained during the course.

Content
The course offers the possibility for people with and without computational or laboratory background to get an introduction into computer-assisted drug design, as well as practical training in a modern chemical laboratory. Using various software suites, the participants will computationally create and screen a virtual compound library for potential active small molecules. The process will involve an introduction to screening a virtual compound library, synthesizing candidate inhibitors, and biological testing against a pharmacologically important drug target.

Lecture notes
Detailed information will be handed out during the course.

Literature
Textbook:

Prerequisites / notice
The class is organized as a two-week block course.

Kick-off meeting and confirmation of registration (Vorbesprechung und Platzvergabe): During the last lecture of the class "Computer-Assisted Drug Design" (535-0022-00).

Ideally, students interested in the course participated and successfully passed the lecture "Computer-Assisted Drug Design" (535-0022-00).

Research Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>511-0003-00L</td>
<td>Practical Methods in Pharmaceutical Sciences</td>
<td>O</td>
<td>8</td>
<td>17A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Abstract
Students get acquainted with scientific working methods and deepen their knowledge in a particular research area.

Electives II

<table>
<thead>
<tr>
<th>Number</th>
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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
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<tr>
<td>511-0004-00L</td>
<td>Research Project</td>
<td>W</td>
<td>15</td>
<td>39A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Abstract
Students get acquainted with scientific working methods and deepen their knowledge in a particular research area.

Prerequisites / notice
Prerequisite: Practical Methods in Pharmaceutical Sciences passed

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>511-0005-00L</td>
<td>Internship</td>
<td>W</td>
<td>10</td>
<td>31A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Abstract
The internship takes place outside universities, the main locations being: pharmaceutical industry, consultancy, health and regulatory authorities and hospitals. Students experience the professional handling of questions in the field of pharmaceutical sciences through their own practical activities

Objective
In an internship the students experience the professional handling of questions in the field of pharmaceutical sciences through their practical activities and be able to implement the knowledge gained, by:
- analysing problems in their complexity and developing solutions in a conceptual way,
- experiencing the aspects of an everyday working environment,
- acquiring key skills,
- establishing contacts for prospective careers.

Content
Work experience outside of university, duration of at least 12 weeks.

An Internship agreement is set up between the student, the company and a member of the teaching staff of the Institute of Pharmaceutical Sciences.

At the end of the internship, the student draws up a formal report.

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<tr>
<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
</tr>
</thead>
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<tr>
<td>511-0006-00L</td>
<td>Consolidation Work</td>
<td>W</td>
<td>7</td>
<td>14A</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Abstract
The Consolidation Work consists of a literature work and provides an opportunity for the students to deeply investigate and consolidate their knowledge in a scientific or technical field of relevance to pharmaceutical sciences / the pharmaceutical industry.

Objective
- students develop their scientific reflection ("Critical Thinking") and independent working skills on a topic relevant to pharmaceutical sciences / the pharmaceutical industry
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing skills

Content
The Consolidation Work consists of a literature work and provides an opportunity for the students to deeply investigate and consolidate their knowledge in a scientific or technical field of relevance to pharmaceutical sciences / the pharmaceutical industry. Students work alone on a topic of their choice over a time period of maximally 12 weeks and elaborate a written review article. Over this time, the student is loosely supervised by a lecturer of the Master Study Program.

Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Only students who fulfill the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

Abstract

In the Master thesis students prove their ability to independent, structured and scientific working. The Master thesis is usually carried out in a subject area of Pharmaceutical Sciences as chosen by the student.

**GESS Science in Perspective**

- see Science in Perspective: Language Courses ETH/UZH
- see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

**Course Units for Additional Admission Requirements**

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0421-AAL</td>
<td>Galenical Pharmacy I+II</td>
<td>E-</td>
<td>4</td>
<td>7R</td>
<td>J.-C. Leroux</td>
</tr>
</tbody>
</table>

**Abstract**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Objective**

Knowledge of the most important pharmaceutical excipients, materials, containers, liquid, solid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solid state, solution and colloidal systems.

**Content**


**Literature**


**Taught competencies**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories assessed
  - Techniques and Technologies assessed
- **Domain B - Method-specific Competencies**
  - Analytical Competencies assessed
  - Decision-making assessed
  - Media and Digital Technologies not assessed
  - Problem-solving assessed
- **Domain C - Social Competencies**
  - Communication not assessed
  - Cooperation and Teamwork not assessed
  - Customer Orientation assessed
  - Leadership and Responsibility not assessed
  - Self-presentation and Social Influence not assessed
  - Sensitivity to Diversity assessed
  - Negotiation not assessed
- **Domain D - Personal Competencies**
  - Adaptability and Flexibility assessed
  - Creative Thinking not assessed
  - Critical Thinking assessed
  - Integrity and Work Ethics not assessed
  - Self-awareness and Self-reflection not assessed
  - Self-direction and Self-management not assessed

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0521-AAL</td>
<td>Pharmacology and Toxicology I+II</td>
<td>E-</td>
<td>4</td>
<td>7R</td>
<td>U. Quitterer</td>
</tr>
</tbody>
</table>

**Abstract**

This course is a condition for admission to the Pharmaceutical Sciences Master. By self-directed learning, students acquire knowledge about basic principles in pharmacology and toxicology, mechanisms of drug action and clinical uses of important classes of drugs.

**Objective**

After the successful completion of this course, students have gained knowledge about basic principles in pharmacology and toxicology, mechanisms of drug action and clinical uses of important classes of drugs.
Contents

Contents of this course are defined by the textbook "Basic and Clinical Pharmacology" by Bertram Katzung. The following sections are exam-relevant.

Section-I Basic Principles, No. 2,3,4.
Section-II, Autonomic Drugs, No. 6,7,8,9,10.
Section-III Cardiovascular-Renal Drugs, No. 11,12,13,15.
Section-IV Drugs with Important Actions on Smooth Muscle, No. 16, 20.
Section-V Drugs that Act in the Central Nervous System, No. 21,22,24,25,26,27,28,29,30,31.
Section-VI Drugs Used to Treat Diseases of the Blood, Inflammation and Gout, No. 34,35,36.
Section-VII Endocrine Drugs, No. 38,39,40,41.

Lecture notes

Course contents are defined by the textbook "Basic and Clinical Pharmacology" by Bertram Katzung and Anthony Trevor. Exam-relevant sections of this book are listed above in the contents section.

Literature

Basic and Clinical Pharmacology

Bertram Katzung

14th edition (2017)

McGraw-Hill Education/Medical

ISBN-10: 1259641155


Abstract

Introduction into the histology and anatomy of the human body, including the musculoskeletal, cardio-respiratory, digestive, endocrine, urinary, reproductive systems, as well as the nervous system and sensory organs.

Objective

Students acquire basic knowledge of the micro- and macro structure of the organ systems in the human body. They understand basic concepts of the relationship between structure and function, and - based on examples - of the relationship between structural changes and disease.

Abstract

Principles of human physiology and clinical pathophysiology.

Objective

Understand the basic principles of human physiology and mechanisms of related clinical pathophysiology.

Abstract

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content

From "Statistics for research" (online)

Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 4: Sampling Distribution of Averages
Ch 5: Normal Distributions
Ch 6: Student's t Distribution
Ch 7: Distributions of Two Variables

From "Introductory Statistics with R (online)"

Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature

- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435

From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435


From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

Abstract

Structure, function, genetics of prokaryotic microorganisms and fungi.
Objective

Content

Literature

Prerequisites / notice
none

551-1323-AAL
Fundamentals of Biology II: Biochemistry and Molecular Biology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The course provides an introduction to Biochemistry / Molecular Biology with some emphasis on chemical and biophysical aspects.

Objective
Topics include the structure-function relationship of proteins / nucleic acids, protein folding, enzymatic catalysis, cellular pathways involved in bioenergetics and the biosynthesis and breakdown of amino acids, glycans, nucleotides, fatty acids and phospholipids, and steroids. There will also be a discussion of DNA replication and repair, transcription, and translation.

Literature

551-0103-AAL
Fundamentals of Biology II: Cell Biology
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective
The goal of this course is to provide students with a wide general understanding cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Content
The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Literature

Prerequisites / notice
none

Pharmaceutical Sciences Master - Key for Type

| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W  | Eligible for credits                | Dr | Suitable for doctorate        |
| E- | Recommended, not eligible for credits | O | Compulsory                    |

Key for Hours

| V  | lecture                          | P  | practical/laboratory course |
| G  | lecture with exercise            | A  | independent project        |
| U  | exercise                         | D  | diploma thesis             |
| S  | seminar                          | R  | revision course / private study |
| K  | colloquium                       |    |                              |

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.

**Pharmaceutical Sciences Bachelor**

**Bachelor Studies (Programme Regulations 2020)**

**First Year Compulsory Subjects**

**First Year Examinations**

**First Year Examination Block 1**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-1001-01L</td>
<td>General Chemistry (for Biol./Pharm.Sc.)</td>
<td>O</td>
<td>4 credits</td>
<td>4V+2U</td>
<td>J. Cvengros</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture deals with a number of basic chemistry concepts. These include (amongst others) chemical reactions, energy transfer during chemical reactions, properties of ionic and covalent bonds, Lewis structures, properties of solutions, kinetics, thermodynamics, acid-base equilibria, electrochemistry and properties of metal complexes.

**Objective**
The course is designed to provide an understanding of the basic principles and concepts of general and inorganic chemistry.

**Literature**

Weiterführende Literatur:


**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
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</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
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</tr>
<tr>
<td></td>
<td>Problem-solving</td>
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</tr>
<tr>
<td></td>
<td>Project Management</td>
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</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
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</tr>
<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Adaptability and Flexibility</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
</tr>
</tbody>
</table>

| Number  | Organic Chemistry I (for Biol./Pharm.Sc./HST) | O    | 4 credits | 4G | C. Thilgen |

**Abstract**
Fundamentals of Organic Chemistry: molecular structure. Bonding and functional groups; nomenclature; resonance and aromaticity; stereochemistry; conformation; bond strength; organic acids and bases; basic reaction thermodynamics and kinetics; reactive intermediates: carbanions, carbenium ions and radicals.

**Objective**
Understanding the basic concepts and definitions of organic chemistry. Knowledge of the functional groups and classes of compounds that are important in biological systems. Foundations for the understanding of the relationship between structure and reactivity.

**Content**

**Lecture notes**
Printed lecture notes are available. Exercises, answer keys and other handouts can be downloaded from the Moodle course "Organic Chemistry I" of the current semester (https://moodle-app2.let.ethz.ch).

**Literature**

**Prerequisites / notice**
The course consists of lectures (36 hours) and problem-solving lessons (20 hours, groups of ca. 25 people). In addition, online exercises are available in the e-learning environment Moodle (Course OC I).

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>
Fundamentals of Biology I: From Molecules to the Biochemistry of Cells

Abstract
The lecture provides an introduction to the basics of biochemistry and molecular biology as well as evolutionary principles. The focus is on bacteria and archaea under consideration of universal concepts.

Objective
Introduction to biochemistry, molecular biology and evolutionary principles

Content
The lecture introduces biology as an interdisciplinary science. Links to physics and chemistry will manifest as biological processes that operate within the laws of thermodynamics and are rooted in elements, molecules and chemical reactions. The transition from geochemistry to biochemistry is discussed and considered in relation to the origin of life. Evolutionary principles are introduced and resulting processes are used as a guiding principle. Unifying concepts in biology are presented, including the structure and function of cellular macromolecules and the ways in which hereditary information is encoded, decoded and replicated. Central principles of universal energy conversion are looked at, starting from redox processes and focusing on bacteria and archaea. Finally, biological processes are put into an ecosystems perspective.

The lecture is divided into different sections:
1. Geochemical perspectives on Earth and introduction to evolution
2. Building blocks of life
3. Macromolecules: Proteins
4. Membranes and transport across the plasma membrane
5. Universal mechanisms of inheritance, transcription and translation
6. Reaction Kinetics, binding equilibria and enzymatic catalysis
7. Essentials of Catabolism
8. Essentials of Anabolism
9. Metabolism and biogeochemical cycling of elements

Lecture notes
The newly conceived lecture is supported by scripts.

Literature
The lecture contains elements of "Brock Biology of Microorganisms", Madigan et al. 15th edition, Pearson und "Biochemistry" (Stryer), Berg et al. 9th edition, Macmillian international.

First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences, which are focused on within the first two years as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

Objective
First identification with Pharmaceutical Sciences; motivation for profiling in the Natural Sciences as a preparation for the specialized studies; sensitization for the duties and the responsibilities of a person with a federal diploma in Pharmacy; information about job opportunities.

Content
Introduction to Pharmaceutical Sciences by selected milestones of research and development. Overview on research activities at the Institute of Pharmaceutical Sciences that is focussed on drug delivery and development (from concepts to prototypes). Sensitization for communication skills and information management. Demonstration of job opportunities in community pharmacies, in the hospital, in industry, and in the public sector by experts in the different fields.

Lecture notes
Handouts for individual lectures.

Prerequisites / notice
Interactive teaching

401-0291-00L | Mathematics I                    | O    | 6 credits | 4V+2U | A. Caspar

Abstract
Mathematics I/II is an introduction to one- and multidimensional calculus and linear algebra emphasizing on applications.

Objective
Students understand mathematics as a language for modeling and as a tool for solving practical problems in natural sciences. Students can analyze models, describe solutions qualitatively or calculate them explicitly if need be. They can solve examples as well as their practical applications manually and using computer algebra systems.
## Eindimensionale diskrete Entwicklungen ##
- linear, exponentiell, begrenzt, logistisch
- Fixpunkte, diskrete Veränderungsrate
- Folgen und Grenzwerte

## Funktionen in einer Variablen ##
- Reproduktion, Fixpunkte
- Periodizität
- Stetigkeit

## Differentialrechnung (I) ##
- Veränderungsrate/-geschwindigkeit
- Differentialquotient und Ableitungsfunktion
- Anwendungen der Ableitungsfunktion

## Integralrechnung (I) ##
- Stammfunktionen
- Integrationstechniken

## Gewöhnliche Differentialgleichungen (I) ##
- Qualitative Beschreibung an Beispielen: Beschränkt, Logistisch, Gompertz
- Stationäre Lösungen
- Lineare DGL 1. Ordnung
- Trennung der Variablen

## Lineare Algebra ##
- Erste Arithmetische Aspekte
- Matrizenrechnung
- Eigenwerte / -vektoren
- quadratische LGS und Determinante

In Ergänzung zu den Vorlesungskapiteln der Lehrveranstaltungen fassen wir wichtige Sachverhalte, Formeln und weitere Ausführungen jeweils in einem Vademecum zusammen.

Dabei gilt:
* Die Skripte ersetzen nicht die Vorlesung und/oder die Übungen!
* Ohne den Besuch der Lehrveranstaltungen verlieren die Ausführungen ihren Mehrwert.
* Details entwickeln wir in den Vorlesungen und den Übungen, um die hier bestehenden Lücken zu schliessen.
* Prüfungsrelevant ist, was wir in der Vorlesung und in den Übungen behandeln.

Siehe auch Lernmaterial > Literatur

**Th. Wihler**
Mathematik für Naturwissenschaften, 2 Bände: Einführung in die Analysis, Einführung in die Lineare Algebra; Haupt-Verlag Bern, UTB.

**H. H. Storrer**
Einführung in die mathematische Behandlung der Naturwissenschaften I; Birkhäuser.

Via ETHZ-Bibliothek: https://link.springer.com/book/10.1007/978-3-0348-8598-0

**Ch. Blatter**
Lineare Algebra; VDF auch als pdf](https://people.math.ethz.ch/~blatter/linalg.pdf)

Die Übungsaufgaben (inkl. Multiple-Choice) sind ein wichtiger Bestandteil der Lehrveranstaltung.
* Es wird erwartet, dass Sie mindestens 75 % der wöchentlichen Serien bearbeiten und zur Korrektur einreichen.
* Der Prüfungssstoff ist eine Auswahl von Themen aus Vorlesung und Übungen. Für eine erfolgreiche Prüfung ist die konzentrierte Bearbeitung der Aufgaben unerlässlich.

**402-0073-00L**  **Physics I**  **O**  **3 credits**  **2V+2U**  **T. M. Ihn**

**Abstract**
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics and elements of quantum mechanics.

**Objective**
Students know and understand the basic ideas of the scientific description of nature. They understand the fundamental concepts and laws of mechanics and they are able to apply them in practical problems. They know the concepts of quantization and quantum numbers.

**Content**
1. Description of Motion
2. The laws of Newton
3. Work and energy
4. Collision problems
5. Wave properties of particles
6. The atomic structure of matter

**Lecture notes**
T. Ihn: Physics for Students in Biology and Pharmaceutical Sciences (unpublished lecture notes)

**Literature**
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Analytical Competencies: assessed
- Problem-solving: assessed

Domain B - Method-specific Competencies
- Cooperation and Teamwork: not assessed
- Sensitivity to Diversity: not assessed

Domain C - Social Competencies
- Critical Thinking: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Domain D - Personal Competencies
- Problem-solving: assessed

Additional First Year Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0667-00L</td>
<td>Communication and Social Competences</td>
<td>O</td>
<td>1 credit</td>
<td>1V</td>
<td>J. Stadelwieser</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction in basic skills for increasing the effectiveness and efficiency of students daily work. Students . . .</td>
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</tr>
<tr>
<td>Objective</td>
<td>1) know tools to &quot;study in a paperless way&quot;; have tried out these tools and made their own conscious choice of useful tools. 2) know tools to work efficiently and goal-oriented in teams. 3) can approach problems methodically correct; know important problem-solving techniques. 4) are able to handle scientific texts and sources correctly; know how to write scientific papers. 5) know how to avoid social problems in workingteams and how to solve them when they exist.</td>
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</tr>
<tr>
<td>Content</td>
<td>corresponding learning goals</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Handouts and working papers.</td>
<td></td>
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</tr>
</tbody>
</table>

| 535-1001-00L | Laboratory Course General Chemistry (for Biology and Pharmacy) | O    | 6 credits | 8P     | S. Gruber, K.-H. Altmann, J. Hall |
| Abstract     | Introduction to the practical work in a chemistry laboratory. The most important manipulations and techniques are treated, as well as the most fundamental chemical reaction types. |
| Objective    | - Knowledge of the basic chemical laboratory methods - Basic knowledge of the scientific approach in experimenting - Observation and interpretation of chemical processes - Keeping of a reliable laboratory journal |
| Content      | - Simple chemical working techniques/methods - Separation techniques - Physical measurements: mass, volume, pH - Ionic solids (salts) - Acid/base chemistry, buffers - Redox reactions - Metal complexes -Titration methods and quantitative spectrometry - Introduction to qualitative analysis |
| Lecture notes | Course manual in German (is handed out to the students at the begin of the lessons) Language: German, English upon request |
| Prerequisites / notice | This practical course causes costs for materials and chemicals. The costs are charged to the students at the end of semester. |

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

Second Year Courses

Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0852-00L</td>
<td>Foundations of Computer Science</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>L. E. Fässler, M. Dahinden</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, introduction to programming, introduction matrices, managing data with lists and tables and with relational databases, universal methods for algorithm design. The students learn to - understand the role of computer science in science, - to control computer and automate processes of problem solving by programming, - choose and apply appropriate tools from computer science, - process and analyze real-world data from their subject of study, - handle the complexity of real-world data.</td>
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</tr>
<tr>
<td>Objective</td>
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</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Year</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0643-13L</td>
<td>Statistics II</td>
<td>3</td>
<td>2021</td>
<td>O. Kalisch</td>
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<tr>
<td>535-0225-00L</td>
<td>Pharmaceutical Analytics I</td>
<td>3</td>
<td>2021</td>
<td>C. Steurer</td>
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</tbody>
</table>
Pharmaceutical Analytics I
535-0223-00L

Objective
Summarize the basic concepts of pharmaceutical analytics in the context of pharmacopeial regulation by Ph. Eur and Ph. Helv.
Discuss the structure of the Ph. Eur.
Analyze and compare most important analytical techniques for pharmacies and pharmaceutical industry

Abstract
This course provides the basic concepts of pharmaceutical analytics in the context of pharmacopeial regulation by Ph. Eur and Ph. Helv.
Summarize the structure of the Ph. Eur.
Summarize the most important pharmacopeias and their commonalities and differences (USP, JP, Ph. Eur., Ph. Helv.)
Discuss the structure of a monograph
Explain qualification of instruments and validation of methods

Lecture notes
The slides of the lectures will be provided.

Literature
Instrumentelle Analytik, G. Rücker, M. Neugebauer, G.G. Willems; Deutscher Apotheker Verlag, Stuttgart
Arzneistoffanalysen; H. J. Roth, K. Eger, R. Troschütz; Deutscher Apotheker Verlag, Stuttgart
Introduction to Pharmaceutical Chemical Analysis; S.H. Hansen, S. Pedersen-Bjergaard, K. Rasmussen; Wiley & Sons

Prerequisites / notice
Requirements for the practical course Pharmaceutical Analytics:
SR 2013: 6 credits Analytics/Pharmaceutical Analytics or 36 credits of compulsory lectures 2nd year
SR 2020: 7 credits Pharmazeutische Analytik I und II or 36 credits of compulsory lectures 2nd year

Typ: O
ECTS: 1
Hours: 1.5G
Lecturers: C. Thilgen, Y. Yamakoshi

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies
Analytical Competencies

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Domain D - Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Domain C - Social Competencies

Bachelor Studies (Programme Regulations 2013)

Second Year

Second Year Core Subjects

Number Title Type ECTS Hours Lecturers
535-0223-00L Pharmaceutical Analytics I O 1 1.5G C. Steuer

Abstract
This course provides the basic concepts of pharmaceutical analytics in the context of pharmacopeial regulation by Ph. Eur and Ph. Helv.
Discuss the structure of the Ph. Eur.
Summarize the most important pharmacopeias and their commonalities and differences (USP, JP, Ph. Eur., Ph. Helv.)
Discuss the structure of a monograph
Explain qualification of instruments and validation of methods

Content
Knowledge in pharmaceutical analytics to fulfill regulatory requirements in pharmaceutical industry based on the pharmacopeia in force. Focus is set on method validation, equipment qualification, identification, purity testing and content determination of active pharmaceutical ingredients and excipients.

Lecture notes
The slides of the lectures will be provided.

Literature
Instrumentelle Analytik, G. Rücker, M. Neugebauer, G.G. Willems; Deutscher Apotheker Verlag, Stuttgart

Prerequisites / notice
Requirements for the practical course Pharmaceutical Analytics:
SR 2004: 2 credits Analytical Chemistry (529-1041-00), lecture Pharmaceutical Analytics
SR 2013: 6 credits Analytics/Pharmaceutical Analytics or 36 credits of compulsory lectures 2nd year

529-1023-00L Physical Chemistry I (for Biology and Pharmacy)
Only for:
- Biologie BSc (Programme Regulations 2013) and
- Pharmaceutical Sciences BSc (Programme Regulations 2013)

Abstract
This course is offered for the last time in autumn 2021.

Objective

Content
Understanding the fundamental thermodynamic properties of chemical and biological systems.

Lecture notes
in process, will be distributed at the beginning of the first lecture

Literature

Prerequisites / notice
Prerequisite: mathematics I-II, functions of multiple variables, partial derivatives.
In particular: There are learning tasks used as performance assessments.

376-0151-00L Anatomy and Physiology I

Abstract
Basic knowledge of the anatomy and physiology of tissues, of the embryonal and postnatal development, the sensory organs, the neuro- muscular system, the cardiovascular system and the respiratory system.

Objective
Basics of anatomy physiology and basics of clinical pathophysiology.

Content
Anatomy and Physiology I (fall term):
- Anatomy and Physiology I (fall term):
  - Basics of cytology, histology, embryology; nervous system, sensory organs, muscles, cardiovascular system, respiratory system

Anatomy and Physiology II (spring term):
- Digestive tract, endocrine organs, metabolism and thermoregulation, skin, blood and immune system, urinary system, circadian rhythm, reproductive organs, pregnancy and birth.

Prerequisites / notice
Requirements: 1st year, scientific part.
Part of the course is read and checked in English.

529-1042-00L Fundamentals of Biology II: Cell Biology

Abstract
The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Prerequisites / notice
Prerequisites:
- 529-1001-01V "Allgemeine Chemie I (für Biol./Pharm.Wiss.)"
- 535-1001-00P "Allgemeine Chemie I (für Biol./Pharm.Wiss.)"
- 529-1011-00P "Organische Chemie I (für Biol./Pharm.Wiss.)"

551-0103-00L Microbiology & Medical Microbiology

Abstract
Practical introduction to microorganisms of medical and veterinary importance, e.g. bacteria, mycobacteria, fungi, viruses, their regulation and detection.

Prerequisites / notice
Prerequisites:
- 529-1001-01V "Allgemeine Chemie I (für Biol./Pharm.Wiss.)"
- 535-1001-00P "Allgemeine Chemie I (für Biol./Pharm.Wiss.)"
- 529-1011-00P "Organische Chemie I (für Biol./Pharm.Wiss.)"
Objective
The goal of this course is to provide students with a wide general understanding cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Content
The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Lecture notes
The lectures are presented in the Powerpoint format. These are available on the WEB for ETH students over the nethz (Moodle). Some lectures are available on the ETH WEB site in a live format (Livestream) at the above WEB site.

Literature

Prerequisites / notice
Some of the lectures are given in the English language. Certain sections of the text-book must be studied by self-instruction.

551-1323-00L
Fundamentals of Biology II: Biochemistry and Molecular Biology
Only for:
- Biologie BSc (Programme Regulations 2013) and
- Pharmaceutical Sciences BSc (Programme Regulations 2013)

Abstract
The course provides an introduction to Biochemistry / Molecular Biology with some emphasis on chemical and biophysical aspects.

Objective
Topics include the structure-function relationship of proteins / nucleic acids, protein folding, enzymatic catalysis, cellular pathways involved in bioenergetics and the biosynthesis and breakdown of amino acids, glycans, nucleotides, fatty acids and phospholipids, and steroids. There will also be a discussion of DNA replication and repair, transcription, and translation.

Lecture notes
none

Literature
mandatory: "Biochemistry", Autoren: Berg/Tymoczko/Stryer, Palgrave Macmillan, International edition (the English version will be preordered at the Polybuchhandlung)

Prerequisites / notice
Some of the lectures are given in the English language.

Laboratory Courses 2nd Year

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-0229-00L</td>
<td>Practical Course Organic Chemistry (for Students of Biology and Pharmaceutical Sciences)</td>
<td>O</td>
<td>8 credits</td>
<td>12P</td>
<td>C. Thilgen, Y. Yamakoshi</td>
</tr>
</tbody>
</table>

Abstract
Analytical part: basic operations for the separation of mixtures of organic compounds (recrystallization, distillation, extraction, chromatography)

Objective
Synthetic part (main part): at least 8 synthetic steps (one- or two-step syntheses).

Content
Analytical part: basic operations for the separation of mixtures of organic compounds. Synthetic part: at least 8 synthetic steps (one- or two-step syntheses) from the following classes of reactions: 1. nucleophilic substitution at C(sp3), 2. elimination or electrophilic addition to C=C, 3. electrophilic aromatic substitution, 4. oxidation, 5. reduction, 6. Grignard reaction, 7. synthesis of a carboxylic acid derivative, 8. Aldol-, Claisen-,- Mannich-, Michael reaction or Robinson annulation.

Lecture notes
Introduction to database searches (Reaxys, SciFinder).

Literature
1) P. Wörnel, M. Bitzer, U. Claus, H. Felber, M. Hübel, B. Vollenweider: Laborpraxis (Bd. 1: Einführung, allgemeine Methoden; Bd. 2: Messmethoden; Bd. 3: Trennungsmethoden; Bd. 4: Analytische Methoden); Birkhäuser Verlag; Basel, 1990.

Prerequisites / notice
The basic reactions of Organic Chemistry and their mechanisms should be known (cf. course 529-1012-00L Organic Chemistry II for Students of Biology, Pharmaceutical Sciences, and Health Sci. and Tech.).

As a prerequisite, all participants need to pass the "Safety Test HCI Chemie_V2 English" (see https://moodle-apo2.let.ethz.ch). A printout of the certificate generated by the system needs to be presented to the teaching assistants prior to starting lab work.

Safety conceptttt: https://chab.ethz.ch/studium/bachelor1.html

Third Year

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Type</th>
<th>Taught Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
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<td></td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Communication</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Adaptability and Flexibility</td>
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<td></td>
<td>Creative Thinking</td>
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<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</table>
### Third Year Core Subjects

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0230-00L</td>
<td>Medicinal Chemistry I</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>J. Hall</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lectures give an overview of selected drugs and the molecular mechanisms underlying their therapeutic effects in disease. The historical and modern-day methods by which these drugs were discovered and developed are described. Structure-function relationships and the biophysical rules underlying ligand-target interactions will be discussed and illustrated with examples.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Basic understanding of therapeutic agents with respect to molecular, pharmacological and pharmaceutical properties.</td>
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</tr>
<tr>
<td>Content</td>
<td>Molecular mechanisms of action of drugs. Structure function and biophysical basis of ligand-target interactions</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Will be provided in parts before each individual lecture.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Attendance of Medicinal Chemistry II in the spring semester.</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Galenical Pharmacy I</th>
<th>O</th>
<th>2</th>
<th>2G</th>
<th>J.-C. Leroux, E. Giger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Principles and technologies for the manufacturing of dosage forms and drug delivery systems. Knowledge of pharm. excipients, materials, containers, liquid and semi-solid dosage forms, their production, function, quality and application. Comprehension of molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in dosage forms.</td>
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<tr>
<td>Objective</td>
<td>Knowledge of the most important pharmaceutical excipients, materials, containers, liquid and semi-solid dosage forms, of their production, function, quality, stability and application. Comprehension of the molecular interactions in solution and colloidal systems. Comprehension of interfacial phenomena and stabilization measures in disperse dosage forms.</td>
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</tr>
<tr>
<td>Content</td>
<td>Introduction and overview of important fundamentals, principles and technologies for the development and manufacturing of dosage forms and drug delivery systems. Overview of the most important pharmaceutical excipients and polymers, their structure, properties and processing; importance of materials properties for containers. Pharmaceutical solvents, fundamentals of solubility and solubilization of drugs. Water treatment processes, sterilization techniques and quality requirements of pharmaceutical water. Parenteral dosage forms and liquid ultrathin films. Surfactants, micelle formation and colloidal systems. Liquid suspensions and emulsions. Stabilization measures in dosage forms.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirements: Knowledge of physical and organic chemistry, biochemistry and biology.</td>
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</tbody>
</table>

#### Taught competencies

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: assessed

- **Domain B - Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: not assessed
  - Problem-solving: assessed
  - Project Management: not assessed

- **Domain C - Social Competencies**
  - Communication: not assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: assessed
  - Negotiation: not assessed

- **Domain D - Personal Competencies**
  - Adaptability and Flexibility: assessed
  - Creative Thinking: not assessed
  - Critical Thinking: assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed

<table>
<thead>
<tr>
<th>Number</th>
<th>Pharmacology and Toxicology I</th>
<th>O</th>
<th>2</th>
<th>2V</th>
<th>U. Quitterer, J. Abd Alla</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The two-semester lecture course will provide a detailed understanding of the fundamentals of drug action and the mechanisms of action and therapeutic use of the important classes of drugs. The lectures are intended for students of pharmaceutical sciences.</td>
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<tr>
<td>Objective</td>
<td>The lectures will provide a comprehensive survey of pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects.</td>
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<tr>
<td>Content</td>
<td>Topics include disease-relevant macroscopic, microscopic, pathochemical and functional disturbances of specific organs and organ systems. The lectures integrate disease pathology with mechanisms of drug action, usage, metabolism, pharmacokinetics, side effects, toxicology, contraindications and dosage of relevant drug classes. Basic principles of clinical pharmacology and pharmacootherapy will be covered.</td>
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<tr>
<td>Lecture notes</td>
<td>A script is provided for each lecture. Scripts define important course contents but do not replace the lectures.</td>
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</tbody>
</table>
The course gives a description and summary of the field of gene technology and its pharmaceutical applications. The course focuses on:

- Students:
  - Are able to analyse, present and discuss common case studies from the pharmacist's practice, based on their basic knowledge in pharmacology.
  - Deepen their knowledge of therapeutic substance classes and therapy guidelines.
  - Are able to analyse the pharmacological profiles of selected drugs in a therapeutic context (e.g. with regard to undesirable other effects and interactions).
  - Are able to compare different drugs and derive their therapy-relevant characteristics.

Content:
- Pharmaceutical case studies from different therapeutic fields comprehend following subject areas:
  - Indication
  - Adverse effects
  - Interactions
  - Contraindications

Recommended reading:
- **Gene Technology**
  - J. Scheuermann

**Prerequisites / notice**

- **535-0525-00L**
  - **Pharmaceutical Cases**
    - **Objective**: The course takes place weekly from 5.11.19-17.12.19. The case studies are worked on in groups of 2-3 students, submitted by e-mail, presented by one group and discussed in the plenum.
    - **Prerequisites / notice**: The lecture Pharmacology and Toxicology I (535-0521-00L) must be attended in parallel to or prior to this course.
    - **Taught competencies**
      - **Domain A - Subject-specific Competencies**: Concepts and Theories, Techniques and Technologies
      - **Domain B - Method-specific Competencies**: Analytical Competencies, Decision-making, Media and Digital Technologies
      - **Domain C - Social Competencies**: Communication, Cooperation and Teamwork, Self-presentation and Social Influence
      - **Domain D - Personal Competencies**: Critical Thinking, Self-direction and Self-management
      - **Literature**
        - *ISDN-13: 978-3-437-42527-7
        - *Teaching materials for the course are available via Moodle.*
      - **Literature**
        - *Laurence Brunton, Bjorn Knollman, Randa Hilal-Dandan.
        - *Goodman and Gilman's The Pharmacological Basis of Therapeutics*
      - **Lecture notes**
    - **535-0333-00L**
      - **Pharmaceutical Biology**
        - Students are able to compare different drugs and derive their therapy-relevant characteristics.
        - **Objective**: The understanding of the biosynthesis of plant-derived natural products. Acquisition of fundamental knowledge on the medical applications of important herbal medicines and of isolated natural products (general disease areas, molecular constituents of medicinal plants and herbal medicines in general, molecular constituents responsible for pharmacological activity, possible mechanisms of action, available clinical data to support medical use).
        - **Content**: The lecture is centered around the discussion of medicinal plants and herbal medicines and their common medical applications. The main areas addressed in the lecture are (a) the structure and biosynthesis of plant constituents (i.e. plant-derived natural products) and (b) the pharmacological effects and therapeutic applications of biogenic drugs of plant origin based on plant extracts as well as isolated natural products. The basic pathways for the biosynthesis of the most important classes of plant-derived natural products are discussed in detail. Likewise, the molecular basis of the pharmacological effects of medicinal plant extracts (and derived herbal medicines) and their individual constituent components (isolated natural products) is broadly addressed. As part of this discussion the availability of clinical data (or lack thereof) to support specific clinical applications of herbal medicines will be repeatedly highlighted. Potential risks associated with the use of herbal medicines are discussed for selected cases.
        - **Lecture notes**
          - *ISDN-13: 978-3-437-42527-7
        - **Literature**
          - *Laurence Brunton, Bjorn Knollman, Randa Hilal-Dandan.
          - *Goodman and Gilman's The Pharmacological Basis of Therapeutics*
        - **Prerequisites / notice**
          - **Requirements**: Lecture courses in basic organic chemistry, biochemistry, and biology
      - **535-0810-00L**
        - **Gene Technology**
          - Students are able to analyse, present and discuss common case studies from the pharmacist's practice, based on their basic knowledge in pharmacology.
          - **Objective**: The course focuses on important methods and technologies and their application for genomic, transcriptomic and proteomic analyses in human biology.
Objective

The course gives an overview of current state-of-the-art and advancement in the fields of gene technology. Herein, the course focuses on genomic, transcriptomic and proteomic analysis and their uses in drug discovery and biomedical applications. The course is structured into lectures and practical examples drawn from the research field. Upon completion, the students are familiar and know current state-of-the art of methods and applications, but are also able to classify, contrast and apply different strategies and methods within the field of gene technology. The course is suited for advanced undergraduate and early graduate students in pharmaceutical sciences or related fields.

Content

I) Genomics and transcriptomics

Methods and Techniques:
- Recombinant DNA technology
- Next generation sequencing methods, sequencing of genomes
- CRISPR technology
Application to human biology:
- Functional genomics/transcriptomics
- Principles of cancer, genetic diseases
- Therapies: cell-based therapies/gene therapies/DNA and RNA vaccination

II) Proteomics

Methods and Techniques:
- Protein cloning and expression
- The antibody molecule
- Measurement and determination of biomolecular interactions
- Protein characterization and engineering
- Modifications and radioactive labelling
Application to human biology:
- Protein therapeutics
- Proteomic approaches for identification of novel disease-related targets and biomarkers

III) Drug discovery: Protein-based libraries

- Immune repertoire mining
- Display and selection technologies
  1. antibody phage display
  2. other polypeptide display technologies
  3. small-molecules display: DNA-encoded chemical libraries

Lecture notes

The lecture series follows the above-described content, and the students are provided with the lecture slides and additional notes. The additional notes are needed for the in-depth study of the individual topics, and to set the frame and content of the in-class group work of the chosen examples.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | assessed |
| Domain D - Personal Competencies | Decision-making | assessed |
| | Problem-solving | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |

535-0830-00L Pharmaceutical Immunology

Abstract

Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Objective

Get Students familiar with basic Immunological concepts of pharmaceutical relevance.

Content

Chapters 1 - 11 of the Janeway's ImmunoBiology, by Kenneth Murphy (9th Edition; Garland).

Literature

Janeway's ImmunoBiology, by Kenneth Murphy (9th Edition).

Paperback

[www.garlandscience.com]

535-0210-00L Radiopharmaceutical Chemistry

Abstract

-Molecular imaging in drug development
- Radiopharmaceutical syntheses
- Knowledge of the physical principles of radioactivity
- Structure and function of radiopharmaceuticals
- Examples of application in diagnosis and therapy in humans
- Targeted radionuclide therapy

Objective

- The students know and are able to describe the different imaging procedures in medicine, especially PET and SPET.
- At the end of the lecture, the students are able to explain and describe the physical basics in connection with radioactivity and the different types of radioactive radiation that are relevant in radiotherapy and nuclear medicine.
- The students know how radionuclides can be produced and extracted.
- The students can describe the structure and function of radiopharmaceuticals and are able to develop strategies for the design of new radiopharmaceuticals.
- The students know selected examples of clinically relevant radiopharmaceuticals and can explain the structure and mechanism of action.
- The students can discuss and apply the principles of internal dosimetry of systemically applied radiopharmaceuticals using selected examples.

Content

- Introduction to molecular imaging.
- Radioactive decay, radiation and radionuclides relevant in nuclear medicine.
- Radionuclide generators
- Radiopharmaceutical synthesis strategies
- Heart, brain and tumour diagnostics with radiopharmaceuticals
- Kinetic modelling with radiopharmaceuticals
- Tumour therapy with radiopharmaceuticals
- Dosimetry of radiopharmaceuticals
- Practical aspect of nuclear medicine and radiotherapy
## Prerequisites / notice

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
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</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
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</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Customer Orientation</td>
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<tr>
<td></td>
<td>Leadership and Responsibility</td>
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<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
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<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tbody>
</table>

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### Laboratory Courses 3rd Year

Respective lectures must be attended before/together with the Laboratory Courses. Special schedule for the Laboratory Courses.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0219-00L</td>
<td>Laboratory Course in Pharmaceutical Analytics</td>
<td>O</td>
<td>3 credits</td>
<td>7P</td>
<td>C. Steuer</td>
</tr>
</tbody>
</table>

**Abstract**

Solving analytical problems; Development and interpretation of analytical methods.

**Objective**

Solving analytical problems; Development and interpretation of analytical methods.

**Content**

Skript Pharmazeutische Analytik Praktikum

**Literature**

- SR 2004: 2 credits Analytical Chemistry (529-1041-00), lecture Pharmaceutical Analytics
- SR 2013: 6 credits Analytics/Pharmaceutical Analytics or 36 credits of compulsory lectures 2nd year.

**Prerequisites / notice**

Requirements:

Safety concept: https://chab.ethz.ch/studium/bachelor1.html

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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0166-00L</td>
<td>Medical Microbiology Practical Course</td>
<td>O</td>
<td>1 credit</td>
<td>1G</td>
<td>A. Lehner</td>
</tr>
</tbody>
</table>

**Abstract**

Basic Training in Practical Medical Microbiology.

**Objective**

Supplement to the parallel lecture in Medical Microbiology. Analysis of simulated clinical specimens using classical methods of Medical Microbiology (microscopy, culture etc.). Main aims are the detection and identification of bacterial, mycobacterial and mycological pathogens as well as microbial susceptibility testing. Safe lab-technical handling is imperative, because pathogens of risk groups 1 and 2 are cultured. Therefore aseptic techniques need to be learned together with the basics in sterilization, disinfection and preservation. Basics of Bio-Safety.

**Content**

Simulated patient specimens representing ca. 50 realistically constructed cases are analysed. The students work in groups and gain insight into the procedures in a routine clinical microbiological laboratory. Using a scriptum, they learn how to identify pathogens and test them for antimicrobial susceptibility. As single groups can work only on a fraction of the cases, results and observations are shared by short presentations through all groups.

**Lecture notes**

The scriptum (in German) will be distributed at the beginning of the course. It contains all protocols necessary for the practical work.

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### 535-0239-00L Practical Course in Medicinal Chemistry

**Abstract**
The course comprises experiments relating to concepts of medicinal chemistry including statistical processing, fitting of experimental data, computer modeling of protein structures, experimental measurement of affinity constants and kinetic dissociation constants for protein ligands. The chemical stability of a drug will be studied. Basic gene cloning and protein expression will be introduced.

**Objective**
Knowledge of experimental methods in drug discovery and development

**Content**
Characterisation of the biophysical and biological properties of drugs.

**Literature**
Original literature

**Prerequisites / notice**
Laboratory course in Pharmaceutical Analytics; Lecture Medicinal Chemistry I in the same semester or earlier.

### 535-0344-00L From Ethnopharmacy to Molecular Pharmacognosy

**Abstract**
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

**Objective**
Basic understanding and awareness of ethnopharmaceutical and ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmaceutical knowledge for world health.

**Content**

**Prerequisites / notice**
Handouts will be provided.

**Literature**

**Taught competencies**
Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: assessed
- Negotiation: assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

### 535-0015-00L History of Pharmacy

**Abstract**
In the lecture, basic knowledge of the history of pharmacy is imparted, taking into account the various historical epochs.

**Objective**
After attending the lecture, the students are able to name significant events in the development of the pharmacy profession, pharmacy and medicines and to place them in a temporal context. They can list sources for working on questions from the history of pharmacy and evaluate their advantages and disadvantages. This enables them to confidently describe the importance of pharmacy as an independent, supporting pillar of the health system, the history of which has many interfaces with medicine, science, social and cultural history.

**Content**
The lecture conveys knowledge about the development of the pharmacist profession from ancient times to the present. Some pharmacists who made significant contributions to pharmacy are presented in more detail and their significance for today's pharmacy is discussed. The social position of pharmacists in society and the legal conditions in different epochs are also discussed. It explains what influence the pharmacists had on the development of the pharmaceuticals, but again the pharmaceuticals on the development of the pharmacists. For this purpose, it is shown how much the meaning, the nature, the type and the composition of pharmaceuticals and the knowledge about them changed over time.

**Literature**
Wird in der ersten Veranstaltung mitgeteilt.

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<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Evidence Based Phytotherapy</th>
<th>W</th>
<th>1 credit</th>
<th>1V</th>
<th>K. Berger Büter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) Identification of drug candidates, b) registration requirements, c) criteria to assess efficacy, d) biomarkers and pharmacokinetics, e) safety and f) principles of extract generation. Important prototypes will be discussed.</td>
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<tr>
<td>Objective</td>
<td>Students should learn the importance of rational (= evidence based) pharmacotherapy with herbal extracts:</td>
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<td>They should get to know the development process of herbal drugs:</td>
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<tr>
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<td>o How are interesting development candidates being identified? What are the strategies?</td>
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<td>o What are the regulatory requirements (traditional use, well-established use, new herbal entities)?</td>
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<td>o What are the selection criteria?</td>
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<td>o Assessment of efficacy (animal-/human studies, biomarker)</td>
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<td></td>
<td>o Pharmacokinetics</td>
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<td>o Safety (Toxicity, unwanted adverse effects, drug-drug interactions)</td>
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<td></td>
<td>o Pharmaceutical quality</td>
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<td>o Securing of herbal identity (collections, agriculture)</td>
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<td></td>
<td>o Quality management</td>
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<td></td>
<td>o selection of appropriate extraction procedures?</td>
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<tr>
<td>Important prototypes</td>
<td>will be presented and critically discussed: see program below</td>
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<tr>
<td>Content</td>
<td>Effective Zeiten 15.45 - 16.30; 16.45-17.30)</td>
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<td>1) 22.09.2021</td>
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<td></td>
<td>Einführung</td>
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<td></td>
<td>Qualität Arzneipflanzen-Fertigprodukte, Monographien (Kommission E, ESCOP, HMPC), Unterschiede hinsichtlich des Registrierungsstatus und -anforderungen: traditional use, well established use und new herbal entities; Extrakte, Qualität Arzneidrogen</td>
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<td>2) 29.9.2021:</td>
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<td></td>
<td>Phasen der klinischen Entwicklung, Grundbegriffe der evidenzbasierten Medizin; Hypericum perforatum</td>
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<td>3) 06.10.2020:</td>
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<tr>
<td></td>
<td>Harpagophyllum spp.; Echinacea ssp</td>
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<td>4) 13.10.2020:</td>
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<td></td>
<td>Lavandula oelum; Iberogast</td>
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<td>5) 20.10.2020:</td>
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<tr>
<td></td>
<td>Cimicifuga racemosa; Serenoa repens</td>
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<td>6) 27.10.2020:</td>
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<tr>
<td></td>
<td>Silibum marianum; Cannabis sativa</td>
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<td>7) 03.11.2020:</td>
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<td>Prüfung (MC)</td>
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<tr>
<td>Lecture notes</td>
<td>Die Skripten werden vor den jeweiligen Vorlesungen per Email an die TeilnehmerInnen versandt</td>
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<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
<th>Vitamins in Health and Disease</th>
<th>W</th>
<th>1 credit</th>
<th>1V</th>
<th>C. Müller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Vitamins are essential organic compounds that cannot be synthesized by an organism and hence, thy have to be acquired from the diet. This lecture will give an overview about the application of vitamins in health and disease.</td>
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<tr>
<td>Objective</td>
<td>The aim of this lecture is a critical examination of the students with the topic of &quot;Vitamins in Health and Disease&quot;. The students will get an overview of vitamins, of their medical applications and the role of the pharmacist with &quot;over-the-counter&quot; products.</td>
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<tr>
<td>Content</td>
<td>Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. However, these are exactly the cases where advice of a pharmacist is requested. A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period.</td>
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<td></td>
<td>The lecture 'Vitamins in Heath and Disease' will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.</td>
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<tr>
<td>Literature</td>
<td>Hand-outs will be distributed during the lecture (partly in English, partly in German). Book recommendation: reference books:</td>
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<tr>
<td></td>
<td>- Handbuch Nährstoffe, Burgerstein, Trias Verlag ISBN 978-3-8304-6071-8</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirements: Basic knowledge in biochemistry and pharmacology. Ability to read and understand scientific publications in English.</td>
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<tr>
<th>Prerequisites / notice</th>
<th>Biotransformation of Drugs and Xenobiotics</th>
<th>W</th>
<th>1 credit</th>
<th>1V</th>
<th>S.-D. Krämer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.</td>
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<tr>
<td>Objective</td>
<td>Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism. Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.</td>
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<tr>
<td>Content</td>
<td>Major reactions of biotransformation.</td>
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<td></td>
<td>Toxic reactions of metabolites. Factors which affect the biotransformation.</td>
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<tr>
<td>Lecture notes</td>
<td>Biotransformation of drugs and xenobiotics</td>
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</tbody>
</table>
In December 2006, Pfizer stopped a large phase III study on the use of Torcetrapib for the prevention of atherosclerosis and cardiovascular disease. 800 million $ in development costs and 21 billion $ in stocks were annihilated overnight. The failure of Torcetrapib has pinpointed the limitations of an extremely reductionist view of atherosclerosis and its prevention by drug therapy. It has also highlighted what high expectations we have in a safe and wide applicability of drugs and of their economical success.
The lecture will cover molecular and cellular processes underlying the development of the nervous system (neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation). The importance of these processes in the context of developmental diseases is discussed.

**Objective**
- On successful completion of the module the student should be able to
  - relate structure and function of the nervous system to its development - apply principles of molecular, cellular, and developmental biology to the development of the nervous system.
  - identify key steps in development underlying neurological syndromes and diseases

**Key skills**
- On successful completion of the module the student should be able to
  - interpret and critically evaluate original research reports
  - apply knowledge and relate experimental approaches from molecular, cellular and developmental biology to the developing nervous system.

**Content**
- The lecture will cover molecular and cellular processes underlying the development of the nervous system. After an introduction to structure and function of the nervous system, we will discuss neurogenesis, cell death, cell migration and differentiation, axon guidance and synapse formation. The importance of these processes in the context of developmental diseases will be discussed.

**Lecture notes**
- Must be downloaded from OLAT: https://www.olat.uzh.ch/olat/dmz/ as BIO344

**Literature**
- The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on OLAT.

**Prerequisites / notice**
- None. Bring something to write and your student ID

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**Computer-Assisted Drug Design**

- **W 1 credit 1V**
- **S. Riniker, G. Landrum**

**Abstract**
The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

**Objective**
The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

**Content**
The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.), and structure-based virtual screening (docking, physics-based models).

**Lecture notes**
Script will be available.

**Literature**
Recommended textbooks:

**Materials and Mechanics in Medicine**

- **W 4 credits 3G**
- **M. Zenobi-Wong, J. G. Snedeker**

**Abstract**
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Objective**
Understanding of physical and technical principles in biomechanics, biomaterials, tissue engineering. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

**Lecture notes**
- Recommended textbook: Biomechanics, Tissue Engineering, Tissue Biomechanics, Implants.

**Literature**
**376-1305-01L** Neural Systems for Sensory, Motor and Higher Brain Functions

*Information for UZH students:*
Enrolment to this course unit only possible at ETH. No enrolment to module BIG394 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

**Abstract**
The course covers the structure, plasticity and regeneration of the adult nervous system (NS) with focus on: sensory systems, cognitive functions, learning and memory, molecular and cellular mechanisms, animal models, and diseases of the NS.

**Objective**
The aim is to give a deepened insight into the structure, plasticity and regeneration of the nervous system based on molecular, cellular and biochemical approaches.

**Content**
The main focus is on the structure, plasticity and regeneration of the NS: biology of the adult nervous system; structural plasticity of the adult nervous system, regeneration and repair: networks and nerve fibers, regeneration, pathological loss of cells.

**Literature**
The lecture requires reading of book chapters, handouts and original scientific papers. Further information will be given in the individual lectures and are mentioned on Moodle / OLAT.

**376-1714-00L** Biocompatible Materials

**Abstract**
Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of biocompatibility is discussed and important techniques from biomaterials research and development are introduced.

**Objective**
The course covers the following topics:
1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

**Content**
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated.

Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

**Lecture notes**
Handouts are deposited online (moodle).

**Literature**
(available online via ETH library)

Handouts and references therein.

**551-0313-00L** Microbiology (Part I)

**Abstract**
Advanced lecture class providing a broad overview on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Objective**
This concept class will be based on common concepts and introduce to the enormous diversity among bacteria and archaea. It will cover the current research on bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Content**
Advanced class covering the state of the research in bacterial cell structure, genetics, metabolism, symbiosis and pathogenesis.

**Lecture notes**
Updated handouts will be provided during the class.

**Literature**
Current literature references will be provided during the lectures.

**Prerequisites / notice**
English

The lecture "Grundlagen der Biologie II: Mikrobiologie" is the basis for this advanced lecture.

**551-0319-00L** Cellular Biochemistry (Part I)

**Abstract**
Concepts and molecular mechanisms underlying the biochemistry of the cell, providing advanced insights into structure, function and regulation of individual cell components. Particular emphasis will be put on the spatial and temporal integration of different molecules and signaling pathways into global cellular processes such as intracellular transport, cell division & growth, and cell migration.

**Objective**
The full-year course (551-0319-00 & 551-0320-00) focuses on the molecular mechanisms and concepts underlying the biochemistry of cellular physiology, investigating how these processes are integrated to carry out highly coordinated cellular functions. The molecular characterisation of complex cellular functions requires a combination of approaches such as biochemistry, but also cell biology and genetics. This course is therefore the occasion to discuss these techniques and their integration in modern cellular biochemistry.

The students will be able to describe the structural and functional details of individual cell components, and the spatial and temporal regulation of their interactions. In particular, they will learn to explain the integration of different molecules and signaling pathways into complex and highly dynamic cellular processes such as intracellular transport, cytoskeletal rearrangements, cell motility, cell division and cell growth. In addition, they will be able to illustrate the relevance of particular signaling pathways for cellular pathologies such as cancer.

**Content**
Structural and functional details of individual cell components, regulation of their interactions, and various aspects of the regulation and compartmentalisation of biochemical processes.

**Lecture notes**
Topics include: biophysical and electrical properties of membranes; viral membranes; structural and functional insights into intracellular transport and targeting; vesicular trafficking and phagocytosis; post-transcriptional regulation of gene expression.

**Literature**
Scripts and additional material will be provided during the semester. Please contact Dr. Alicia Smith for assistance with the learning materials. (alicia.smith@bc.biol.ethz.ch)

**Prerequisites / notice**
To attend this course the students must have a solid basic knowledge in chemistry, biochemistry and general biology. The course will be taught in English.

**752-1003-00L** Food Chemistry II

**Abstract**
To familiarize with the structure, properties and reactivity of food constituents. To understand the relationship between the multiple chemical reactions and the quality of food.
Objective

Recognize chemical structures of the main ingredients and be able to draw them themselves
Understand foods as complex systems and be able to make connections between chemical structures, chemical reactions and their influence on quality.
Recognize chemical reactions of lipid oxidation, Maillard reaction and enzymatic reactions and be able to formulate them themselves.

Content

This lecture introduces the basic principles of injury mechanics and rehabilitation
Descriptive chemistry of food constituents (proteins, lipids, carbohydrates, plant phenolics, flavour compounds).
Reactions which affect the colour, flavour, texture, and the nutritional value of food raw materials and food products during processing, storage and preparation in a positive or in a negative way (e.g. lipid oxidation, Maillard reaction, enzymatic browning).
Links to food analysis, food processing, and nutrition.

Topics:
- Lipid oxidation, Maillard reaction, structural proteins/enzymes
- Food as complex systems
- Chemical reactions and reaction mechanisms
- Selected (possibly changing) food chemistry topics (e.g. sweeteners, polysaccharides, from olive to margarine, etc.)

Lecture notes

The lectures Food Chemistry I and Food Chemistry II constitute a unit.

Literature

The lectures are supplemented with handouts.


752-4005-00L Food Microbiology I

Abstract

This lecture is the first part of a one-year course. It offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts and molds present in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.

Objective

The lecture offers insights into the fundamentals and applications of Food Microbiology. Contents include basic microbiology of the different bacteria, yeasts, molds and protozoa in foods, as well as the occurrence and control of foodborne pathogens and spoilage organisms.
The focus of this first part of the two part lecture (Food Micro II is offered in the FS) will be on the organisms, but also on the factors which determine spoilage and foodborne disease.

Content

1. History of Food Microbiology
1.1. Short synopsis of foodborne microorganisms
1.2. Spoilage of Foods
1.3. Foodborne Disease
1.4. Food Preservation
1.5. VIP's of Food Microbiology
2. Overview of Microorganisms in Foods
2.1 Origin of foodborne Microorganisms
2.2. Bacteria
2.3. Yeasts
2.4. Molds
3. Microbial Spoilage of Foods
3.1. Intrinsic and Extrinsic Parameters
3.2. Meats, Seafoods, Eggs
3.3. Milk and Milk Products
3.4. Vegetable and Fruit Products
3.5. Miscellaneous (baked goods, nuts, spices, ready-to-eat products)
3.6. Drinks and Canned Foods
4. Foodborne Disease
4.1. Significance and transmission of Foodborne pathogens
4.2. Staphylococcus aureus
4.3. Gram-positive Sporeformers (Bacillus & Clostridium)
4.4. Listeria monocyogenes
4.5. Salmonella, Shigella, Escherichia coli
4.6. Vibrio, Yersinia, Campylobacter
4.7. Brucella, Mycobacterium
4.8. Parasites
4.9. Viruses and Bacteriophages
4.10. Mycotoxins
4.11. Bioactive Amines
4.12. Miscellaneous (Antibiotic-resistant Bacteria, Biofilms)

Lecture notes

Electronic copies of the presentation slides (PDF) and additional material will be made available for download.

Recommendations will be given in the first lecture.

737-2017-00L Biomechanics of Sports Injuries and Rehabilitation

Abstract

This lecture introduces the basic principles of injury mechanics and rehabilitation focussing on sports injuries.

Objective

Within the scope of this lecture you will learn the basic principles of trauma biomechanics. Based on examples from sports, you will get to know different mechanisms that can possibly result in injury. Investigating the background and cause of injury should allow you to assess the injury risk for sports activities. Furthermore you should be able to develop measures to prevent such injury.

Content

This lecture deals with the basic principles of injury mechanics and rehabilitation. Mechanisms that can result in injury are presented. Furthermore possibilities to prevent injuries are discussed. Thereby the lecture focuses on sports injuries.

Lecture notes

Handouts will be made available.

Literature


Prerequisites / notice

A course work is required. The mark of this course work contributes to the final credits for this lecture. Details will be given during the first lecture.

752-4009-00L Molecular Biology of Foodborne Pathogens

Abstract

The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective

Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.
Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage for both diagnostics and antimicrobial intervention.

Electronically copies of the presentation slides (PDF) and additional material will be made available for download to registered students. Recommendations will be given in the first lecture. Lectures (2 hours) will be held as a single session of approximately 60+ minutes (10:15 until approx. 11:15 h), without break!

### 752-SI03-00L Functional Microorganisms in Foods

**Abstract**

This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

**Objective**

To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

**Content**

This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- Legal and protection issues related to functional foods
- Industrial biotechnology of flavor and taste development
- Safety of food cultures and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

### 752-SI01-00L Dietary Etiologies of Chronic Disease

**Objective**

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Content**

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

**Taught competencies**

- Domain A - Subject-specific Competencies: Concepts and Theories assessed, Analytical Competencies assessed, Decision-making assessed, Problem-solving assessed, Project Management not assessed.
- Domain B - Method-specific Competencies: Communication not assessed, Cooperation and Teamwork not assessed.
- Domain C - Social Competencies: Creative Thinking not assessed, Critical Thinking assessed.

Electronic copies of the presentation slides from lectures will be provided.

### 752-SI05-00L Epidemiology and Prevention

**Objective**

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

**Content**

The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Taught competencies**

- Domain A - Subject-specific Competencies: Concepts and Theories assessed, Analytical Competencies assessed, Decision-making assessed, Problem-solving assessed, Project Management not assessed.
- Domain C - Social Competencies: Communication not assessed, Cooperation and Teamwork not assessed.
- Domain D - Personal Competencies: Creative Thinking not assessed, Critical Thinking assessed.

### 752-SI01-00L Food Biotechnology

**Objective**

Basic information for understanding biotechnology applied to food processing will be presented. This will include a presentation of the physiology of important productive microorganisms used in food fermentations; microbial and fermentation kinetics, and design and operation of fermentation processes and bioreactors; and application of modern molecular tools for food biotechnology.

**Content**

The main goal for this course is to provide students with basic information for understanding biotechnology applied to food processing. For the students, the aim will be:

- To understand the important role of microbial physiology and molecular tools for food biotechnology;
- To understand basic principles of fermentation biotechnology, with particular emphasis on metabolism and kinetics for food applications.
Biotechnology has been defined as any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses. In this course, basic knowledge for understanding biotechnology as applied to food processing will be presented. This course builds on the application of principles learned from other basic courses in the Bachelor program, especially microbiology and microbial metabolism, molecular biology, biochemistry, physics and engineering. Students will learn about the physiology of important productive microorganisms (lactic acid bacteria, bifidobacteria, propionibacteria and fungi) used in food fermentations, closely related to applications in biotechnology. Microbial and fermentation kinetics, and design and operation of fermentations and bioreactors used for both research and industrial scale production of traditional foods and modern food ingredients will be presented. This part will be illustrated by examples of food fermentation processes, representative of specific challenges. Finally, the application of modern molecular tools to food biotechnology will be discussed.

Lecture notes
A copy of the power point slides from each lecture will be provided.

Literature
A list of references will be given at the beginning of the course for the different topics presented during the course.

**GESS Science in Perspective**

*see GESS Science in Perspective: Language Courses*

*see GESS Science in Perspective: Type A: Enhancement of Reflection Capability*

*Recommended GESS Science in Perspective (Type B) for D-CHAB.*

### Pharmaceutical Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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### Key for Hours

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<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
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<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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</tbody>
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### ECTS

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Pharmacy Master

Core Courses I

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences. Students work in small groups on a chosen topic, they write a mini-review and present their work on a one day symposium.

Objective

The main objectives of this course are:

- students develop their scientific reflection (Critical Thinking) and working skills by working independently on a relevant pharmaceutical topic
- students gain in-depth knowledge of the topic investigated
- students train their scientific writing and presentation skills
- students train their ability to plan a project and work in a team

Content

The Course Drug Seminar takes place during the first 7 weeks of the 1. Master semester. It is a compulsory course of the MSc Pharmacy curriculum and an elective course in the MSc PharmSciences.

The course provides a platform for the investigation, presentation and discussion of a topic with relevance to the field of pharmaceutical sciences.

During the course, students work in small teams on a topic of their choice and elaborate a written mini-review and an oral presentation. Each team is tutored by a lecturer of the Institute of Pharmaceutical Sciences. The work is mainly based on literature search / review, but may also involve conducting interviews or site visits, if appropriate. The final presentations of all groups will take place in the framework of a dedicated Symposium held in the middle of the semester.

Prerequisites / notice

Only for students of MSc Pharmacy and MSc Pharmaceutical Sciences.

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>535-0041-00L</td>
<td>Pharmacology and Toxicology III</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>M. Detmar, U. Quitterer</td>
</tr>
</tbody>
</table>

Abstract

The course is divided into two parts. The first part provides a detailed understanding of drugs and pharmacotherapy of infectious diseases and cancer. The second part gives an overview of the field of pharmacoepidemiology with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Objective

The course advances basic knowledge in pharmacology and toxicology. Special emphasis is placed on the interrelationship between pharmacological, pathophysiological and clinical aspects of drug therapy in the fields of infectious diseases and cancer. The course also provides an overview of the field of pharmacoepidemiology, with a special focus on the role of genetic polymorphisms in disease susceptibility, drug response and adverse effects.

Content

Topics include the pharmacology and pharmacotherapy of infectious diseases and cancer. In the field of pharmacoepidemiology, the course is focused on genetics, genome-wide association studies, genetic disease predisposition, examples of genetic variability of drug metabolism and drug responses, identification of new drug targets, relevance of pharmacoepidemiology for clinical drug development, and toxicogenomics.

Lecture notes

A script is provided for each lecture course. The scripts define important and exam-relevant contents of lectures. Scripts do not replace the lecture.

Literature

Recommended reading:
The classic textbook in Pharmacology:
Goodman and Gilman’s The Pharmacological Basis of Therapeutics
Laurence Brunton, Bjorn Knollman, Randa Hilal-Dandan.
ISBN-10: 1259584739

- or

Klaus Aktories, Ulrich Förstermann, Franz Hofmann, Klaus Starke.
Allgemeine und spezielle Pharmakologie und Toxikologie.
Urban & Fischer (Elsevier, München)

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<tr>
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<tbody>
<tr>
<td>535-0050-00L</td>
<td>Pharmacoepidemiology and Drug Safety</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>A. Burden, S. Russmann</td>
</tr>
</tbody>
</table>

Abstract

Introduction to the principles, methods and applications of pharmacoepidemiology and drug safety. Drug safety in the pharmaceutical industry and regulatory authorities, but also for hospital and office pharmacists. Another focus is the evaluation and interpretation of pharmacoepidemiological drug safety studies in the medical literature and the evaluation of benefits vs. risks.

Objective

Objectives:

- To familiarize participants with the principle methods and applications of pharmacoepidemiology and drug safety that is relevant for industry, regulatory affairs, but also for clinical pharmacists in hospitals and office pharmacies.
- Perform independently a causality assessment of suspected adverse drug reactions in patients
- Study designs and biostatistics used for the quantitative evaluation of drug safety
- Setup of programs that can effectively reduce medication errors and improve drug safety in clinical practice, particularly in hospitals

Content

- Historical landmarks of drug safety
- Pharmacovigilance and causality assessment
- Drug safety in premarketing clinical trials
- Descriptive, cohort and case-control drug safety study designs; Data analysis and control of confounding
- Pharmacoepidemiology and regulatory decision making in drug safety; Risk management plans (RMPs)
- Medication errors, clinical pharmacology / clinical pharmacy
- Clinical Decision Support Systems, Interventional Pharmacoepidemiology
- Pharmacoepidemiological databases, ‘Big Data’
- Interactive discussion of many real-life examples for each topic

Lecture notes

This course will be a combination of formal lectures, group discussions and self-directed studies. Course material will be taught through seminars, case studies in small groups.

Reading material and scripts will be provided for each week.
In this course, various topics related to the development, GMP production and application of therapeutic proteins will be discussed. Furthermore, students will expand their training in pharmaceutical immunology and will be introduced to the basic concepts of pharmaceutical product quality management.

**Objective**

Students know and understand:
- basic mechanisms and regulation of the immune response
- the pathogenic mechanisms of the most important immune-mediated disorders
- the most frequently used expression systems for the production of therapeutic proteins
- the use of protein engineering tools for modifying different features of therapeutic proteins
- the mechanism of action of selected therapeutic proteins and their application
- basic concepts in the GMP production of therapeutic proteins

**Content**

The course consists of two parts:

- In a first part, students will complete their training in pharmaceutical immunology (Chapter 13 - 16 Immunobiology VIII textbook). This part particularly focuses on the pathogenic mechanisms of immune-mediated diseases. Deepened knowledge of immunology will be relevant for understanding the mechanism of action of many therapeutic proteins, as well as for understanding one major concern related to the use of protein-based drugs, namely, immunogenicity.
- The second part focuses on topics related to the development and application of therapeutic proteins, such as protein expression, protein engineering, reducing immunogenicity, and GMP production of therapeutic proteins. Furthermore, selected examples of approved therapeutic proteins will be discussed.

**Lecture notes**

Handouts to the lectures will be available for downloading under http://www.pharma.ethz.ch/scripts/index

**Literature**

- Janeway's Immunobiology, by Kenneth Murphy (9th Edition), Chapters 12-16
- Lecture Handouts
- Paper References provided in the Scripts
- EMEA Dossier for Humira

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**Core Courses (Clinical Subjects)**

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</table>

**Abstract**

This course provides basic clinical and pharmaceutical knowledge and skills for triage, diagnostics and therapy support of the most common diseases.

**Objective**

Students
- know and understand the pathomechanisms and clinical lead and warning symptoms (red flags) of the most common diseases in the fields listed below.
- can use this knowledge to triage patients: i.e. analyse simple symptoms and diseases, make a tentative diagnosis and recommend suitable medication or further examinations or measures.
- know the therapeutic guidelines, classes of active ingredients and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).

**Content**

"Pharmaceutical Care" und "Health Care";
Häufigste Erkrankungen und Therapien der
- Allergologie
- Angiologie und Hämatologie
- Dermatologie
- Endokrinologie und Diabetologie
- Gastroenterologie
- Infektiologie
- Kardiologie
- Neurologie
- Ophthamologie
- Otorhinolaryngologie
- Pneumologie
- Psychiatrie
- Rheumatologie
- Urologie

Grundlagen der Chiropraktischen Medizin und Physiotherapie.

**Lecture notes**

Provided via myStudies.

**Literature**

As stated in the lecture notes.
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

Literature

Further references will be provided in the course.

Prerequisites / notice

Please note that the assessment of this course must be passed (not compensable).

The performance assessment of the course takes place in two written online partial examinations. The overall grade results from the average of the grades of both partial examinations. If the overall grade is unsatisfactory, both partial examinations must be repeated.

The courses Pharmacology and Toxicology I and II and Pathobiology provide indispensable basics which students must master at the beginning of the semester in order to successfully complete the course.

Pharmacology and Toxicology III must be visited at the same time.

Electives

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<tr>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>535-0423-00L</td>
<td>Drug Delivery and Drug Targeting</td>
<td>W</td>
<td>2</td>
<td>1.5V</td>
<td>J.-C. Leroux, A. Steinauer</td>
</tr>
</tbody>
</table>

Abstract
The students gain an overview on current principles, methodologies and systems for controlled delivery and targeting of drugs. This enables the students to understand and evaluate the field in terms of scientific criteria.

Objective
The students dispose of an overview on current principles and systems for the controlled delivery and targeting of drugs. The focus of the course lies on developing a capacity to understand the involved technologies and methods, as well as an appreciation of the chances and constraints of their therapeutic usage, with prime attention on anticancer drugs, therapeutic peptides, proteins, nucleic acids and vaccines.

Content
The course covers the following topics: drug targeting and delivery principles, macromolecular drug carriers, liposomes, micelles, micro/nanoparticles, gels and implants, administration of vaccines, targeting at the gastrointestinal level, synthetic carriers for nucleic acid drugs, ophthalmic devices, novel trends in transdermal and nasal drug delivery and 3D printing of drug delivery systems.

Lecture notes
Selected lecture notes, documents and supporting material will be directly provided or may be downloaded from the course website.

Literature

Further references will be provided in the course.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

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<tr>
<td>535-0250-00L</td>
<td>Biotransformation of Drugs and Xenobiotics</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>S.-D. Krämer</td>
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</tbody>
</table>

Abstract
Knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Objective
Goals: knowledge of the major reactions of biotransformation in drug therapy, prediction of possible metabolites of drugs and xenobiotics, recognition of structure elements and reactions which can lead to toxic metabolites. Knowledge of inter- and intraindividual factors influencing metabolism.

Content
Major reactions of biotransformation. Major enzymes and reaction partners involved in the biotransformation of drugs and xenobiotics. Toxic reactions of metabolites. Factors which affect the biotransformation.

Lecture notes
Biotransformation of drugs and xenobiotics

Literature

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>535-0546-00L</td>
<td>Patents</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>A. Koepf, P. Pliska</td>
</tr>
</tbody>
</table>

Abstract
Knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on pharmaceuticals, introduction into intellectual property, prosecution of patent applications; patent information; exploitation and enforcement of patents; peculiarities in pharmaceutics and medicine; social, political and ethical aspects; Trademarks

Objective
Basic knowledge in the field of industrial property, especially of patents and trademarks, with particular emphasis on the chemical, pharmaceutical and biotech field.
1. Introduction into industrial property (patents, trademarks, industrial designs);
2. Prosecution of patent applications (patentability);
3. Patent information (patent publications, databases, searches);
4. Exploitation and enforcement of patents (possibilities of exploitation, licenses, parallel imports, scope of protection, patent infringement);
5. Peculiarities in pharmacoeconomics and medicine (complementary protection certificates, experimental use exemption, therapy and diagnosis, medical indication);
6. Social, political and ethical aspects (patents and prices for medicinal products, traditional knowledge and ethnopharmacology, bioprospecting and biopiracy, human DNA inventions);
7. Trademarks, types of trademarks, grounds for refusal, peculiarities of pharma-trademarks.

A script is provided in electronic form during the lecture.


Wird in der ersten Veranstaltung mitgeteilt.

Prerequisites / notice

Domain A - Subject-specific Competencies
Concepts and Theories
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
Adaptability and Flexibility
Creative Thinking
Critical Thinking
Integrity and Work Ethics
Self-awareness and Self-reflection
Self-direction and Self-management

Domain B - Method-specific Competencies
Techniques and Technologies

Domain C - Social Competencies

Domain D - Personal Competencies

W 1 credit 1V S. Ruppen

From Ethnopharmacology to Molecular Pharmacognosy
Basic understanding and awareness of ethnopharmacological issues and research. Knowledge of methods used in drug discovery from natural sources. Discussion of the issues around law and international treaties. Importance of ethnopharmacological knowledge for world health.

B. Frei Haller, A. Lardos

Introduction into ethnopharmacology and related disciplines; definitions of terms, working methods, research projects, bioprospecting. Traditional medicinal plants of different cultures and their role in modern Western medicine (rational application of traditional uses). Historical data as sources for drug research. Today’s "fashion plants." Empirical, traditional knowledge versus Evidence Based Medicine. The role of biodiversity (CBD, Rio 1992; Nagoya, 2010) and problems associated with drug discovery from natural products. Screening strategies for drug discovery (random screening versus screening based on cultural, ecological, ethnopharmacological, chemotaxonomic criteria). Traditional knowledge in relation to the fight against malaria and its implementation in research, product development and development cooperation. Introduction to and selected examples of herbal drugs and poisons, mode of action, and their ethnopharmacological importance. Critical analysis of bioprospecting as a drug discovery strategy.

Handouts will be provided.

B. Frei Haller, A. Lardos
Vitamins are essential organic compounds that cannot be synthesized by an organism and hence, they have to be acquired from the diet.

The aim of this lecture is a critical examination of the students with the topic of "Vitamins in Health and Disease". The students will get an overview of vitamins, of their medical applications and the role of the pharmacist with "over-the-counter" products.
Deficiencies of particular vitamins result in specific diseases such as for example scurvy (vitamin C deficiency). Such disease patterns are usually easily recognized and facile to be treated. The clinical utility of supplementation concerns people with severe deficiencies and a risk of complications. Latent vitamin deficiencies might result in variable disorders and risks. As an example neurological disorders in elderly as a consequence of chronic lack of vitamin B12 should be mentioned. Subclinical deficiencies are often difficult to assess. These are exactly the cases where advice of a pharmacist is requested. A large intake of vitamins by over-supplementation or food fortification might be dangerous (hypervitaminosis). This is in particular the case for fat-soluble vitamins or in the case of constant intake of high amounts of water-soluble vitamins over a long time period. The lecture 'Vitamins in Health and Disease' will give an overview over the history and applications of vitamins and their functions to preserve good health. The utility of vitamin supplementation during conditions of deficiencies, potential consequences of a latent deficiency as well as risks of over-supplementation will be discussed.

Lecture notes
Hand-outs will be distributed during the lecture (partly in English, partly in German).

Literature
Book recommendation: reference books:
- Handbuch Nährstoffe, Burgerstein, Trias Verlag ISBN 978-3-8304-6071-8

Prerequisites / notice
Requirements: Basic knowledge in biochemistry and pharmacology. Ability to read and understand scientific publications in English.

Evidenz Based Phytotherapy
Based on epidemiology, economic importance and evidence-based medicine, basic principles of rational phytotherapy will be discussed: a) Identification of drug candidates, b) registration requirements, c) criteria to assess efficacy, d) biomarkers and pharmacokinetics, e) safety and f) principles of extract generation. Important prototypes will be discussed.

Objective
Students should learn the importance of rational (= evidence based) pharmacotherapy with herbal extracts:
- They should get to know the development process of herbal drugs:
  - How are interesting development candidates being identified? What are the strategies?
  - What are the regulatory requirements (traditional use, well-established use, new herbal entities)?
  - What are the selection criteria?
  - Assessment of efficacy (animal-/human studies, biomarker)
  - Pharmacokinetics
  - Safety (Toxicity, unwanted adverse effects, drug-drug interactions)
  - Pharmaceutical quality
  - Securing of herbal identity (collections, agriculture)
  - Quality management
  - selection of appropriate extraction procedures

Important prototypes will be presented and critically discussed: see program below

Content
Effective Zeiten 15.45 - 16.30; 16.45-17.30

- 29.9.2021: Phasen der klinischen Entwicklung, Grundbegriffe der evidenzbasierten Medizin; Hypericum perforatum
- 20.10.2020: Cimicifuga racemosa; Serenoa repens
- 13.10.2020: Lavandula oelum; Iberogast
- 6.10.2020: Harpagophytm spp.; Echinacea ssp
- 3) 27.10.2020: Silybum marianum; Cannabis sativa

Lecture notes
Die Skripten werden vor den jeweiligen Vorlesungen per Email an die TeilnehmerInnen versandt

Computer-Assisted Drug Design
The lecture series provides an introduction to computer applications in medicinal chemistry. The topics cover molecular representations and similarity, ligand-based virtual screening, and structure-based virtual screening. All theoretical concepts and algorithms presented are illustrated by practical applications and case studies.

Objective
The students will learn how molecules can be represented in computers and how molecular similarity is calculated. They will learn the concepts of ligand-based and structure-based virtual screening to identify potential drug candidates, and understand possibilities and limitations of computer-assisted drug design in pharmaceutical chemistry. As a result, they are prepared for professional assessment of computer-assisted drug design studies in medicinal chemistry projects.

Content
- The topics include molecular representations and similarity, ligand-based virtual screening (similarity search, QSAR, etc.), and structure-based virtual screening (docking, physics-based models).

Lecture notes
Script will be available.

Literature
Recommended textbooks:

Methods in Drug Design

Methods in Drug Design does not take place this semester.
### Computer-Assisted Drug Design (Practical Course) 535-0022-00L

**Abstract**
The practical course is open for master and graduate students to get an introduction into hands-on computer-assisted drug design. The course offers the possibility for people with and without computational and or laboratory background to get an introduction into computer-assisted drug design, as well as practical training in a modern chemical laboratory. Using various software suites, the participants will computationally create and screen a virtual compound library for potential active small molecules. The process will involve an introduction to screening a virtual compound library, synthesizing candidate inhibitors, and biophysical testing against a pharmacologically important drug target.

**Objective**
Participants become familiar with state-of-the-art methodologies in a real-life computer-aided medicinal chemistry project. Participants work as small teams, perform literature research and discuss recent research findings. A seminar talk is to be given presenting the molecular design strategy chosen and the results obtained during the course.

**Content**
The course offers the possibility for people with and without computational and or laboratory background to get an introduction into computer-assisted drug design, as well as practical training in a modern chemical laboratory. Using various software suites, the participants will computationally create and screen a virtual compound library for potential active small molecules. The process will involve an introduction to screening a virtual compound library, synthesizing candidate inhibitors, and biophysical testing against a pharmacologically important drug target.

**Lecture notes**
Detailed information will be handed out during the course.

**Literature**

**Prerequisites / notice**
The class is organized as a two-week block course. The number of participants is limited.

Kick-off meeting and confirmation of registration (Vorbesprechung und Platzvergabe): During the last lecture of the class "Computer-Assisted Drug Design" (535-0022-00)

Ideally, students interested in the course participated and successfully passed the lecture "Computer-Assisted Drug Design" (535-0022-00).

### Practical Pharmacy I

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</table>

**Abstract**
This course provides basic knowledge relevant to pharmacy and its application in nephrology, phytotherapy, complementary medicine, wound care and pharmaceutical care.

**Objective**
Students know and understand the therapeutic concepts of the mentioned topics and their application in practice.

**Content**
- complementary medicine
- phytotherapy
- wound care
- pharmaceutical care 2
- nephrology

**Lecture notes**
Provided via myStudies.

**Literature**
As specified in the lecture notes

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<tr>
<th>Number</th>
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</table>

**Abstract**
This course provides basic clinical and pharmaceutical knowledge and its application for triage, diagnostics and therapy support for the most common diseases in geriatrics, gynaecology, oncology, paediatrics and neurology (epilepsy). In addition, the role of nutrition in special life situations and in selected health disorders is taught.

**Objective**
- know the therapeutic guidelines, drug classes and selected, practice-relevant drugs (including indications and the most frequent and important dosages, adverse drug reactions, interactions and contraindications).

(For detailed learning objectives, see the guideline)
**Practical Pharmacy II**

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tbody>
<tr>
<td>535-5502-00L</td>
<td>Pharmaceutical Manufacturing in Small Quantities (Compounding)</td>
<td>O</td>
<td>3 credits</td>
<td>5G</td>
<td>P. G. Tiefenböck, A. Romagna</td>
</tr>
<tr>
<td>Abstract</td>
<td>Pharmaceutical Manufacturing relevant for the community pharmacy considering the &quot;GMP-Regeln in kleinen Mengen&quot; of the Pharmacopoeia: The preparation of extemporaneous products covering the most common forms under consideration of their Risks and Quality Assurance.</td>
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<tr>
<td>Objective</td>
<td>The students are able to produce pharmaceutical relevant drug Systems without further assistance, lege artis, applying the right techniques and material. The production and packaging has to follow GMP rules and tailored for the patients need. The quality control and correct documentation have to be followed. The students know the most relevant specifications, concentration and dosing ranges of common APIs and excipients. The students are familiar with the relevant literature (Pharmacetical and legal basis) regarding the Pharmaceutical manufacturing relevant for the community pharmacies.</td>
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<tr>
<td>Content</td>
<td>Vermittlung der wichtigsten Kenntnisse, Arbeitsschritte und -techniken im Bereich der Arzneimittelherstellung in kleinen Mengen (Formula) mit Fokus auf die Herstellung, Qualitätssicherung und Risikobeurteilung einschliesslich der patientenspezifischen Abgabepraxis.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Safety concept: <a href="https://chab.ethz.ch/studium/bachelor1.html">https://chab.ethz.ch/studium/bachelor1.html</a></td>
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<tr>
<td>535-5503-00L</td>
<td>Institutional Pharmacy</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>P. Wiedemeier, J. Beney, M. Lutters, I. S. Vogel Kahmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Organisation of institutional environments (emergency hospitals), with special focus on the medication process and institutional pharmaceutical care (continuum of care).</td>
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<tr>
<td>Objective</td>
<td>Students understand the concept of continuum of care and its practical implementation. They know the medication process within an institutional environment. They are able to find the necessary information and deal with problems in connection with pharmaceuticals, to evaluate them and to communicate and documentate their findings adequately. They know how a hospital is organised (procedures, possible problems), responsibilities of the different members of the staff and, most importantly, what the function of a hospital pharmacy is.</td>
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<tr>
<td>Content</td>
<td>Principals of the organisation of institutional environments (emergency hospitals), with special focus on medication processes and institutional pharmaceutical care (circulation of medication, continuum of care). Hygiene regulations, medical products, applications, drug formularies, patient files, SOAP notes, kardex study. Participation at interdisciplinary visits, internal trainings and doctors' reports as well as visitation of the emergency room. Drug interaction, generic substitution, quality management and pharmacovigilance.</td>
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<tbody>
<tr>
<td>535-5524-00L</td>
<td>Clinical Trainings</td>
<td>O</td>
<td>2 credits</td>
<td>3G</td>
<td>A. Gutzeit, D. Stämpfli, P. Wiedemeier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Basic training on and around patients with practical confrontation. The path of acute patients from patient presentation, through triage and diagnostics to therapy.</td>
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</tr>
</tbody>
</table>

**Compensatory Courses**

The elective courses can be used as compensatory courses.

**GESS Science in Perspective**

see Science in Perspective: Language Courses ETH/UZH

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-CHAB

**Master’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0680-00L</td>
<td>Master’s Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>40D</td>
<td>Lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Only students who fulfill the following criteria are allowed to begin with their master thesis: a. successful completion of the bachelor programme; b. fulfilling of any additional requirements necessary to gain admission to the master programme.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>During the Master's thesis students prove their ability to independent, structured scientific work. The Master's thesis is usually carried out in a subject area of Pharmaceutical Sciences as chosen by the student.</td>
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</tr>
</tbody>
</table>

**Course Units for Additional Admission Requirements**

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>535-0135-AAL</td>
<td>Clinical Chemistry I</td>
<td>E-</td>
<td>1 credit</td>
<td>2R</td>
<td>M. Hersberger</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction into fundamentals of laboratory diagnostics and overview of the laboratory parameters concerning inflammation, lipid metabolism, myocardial infarction, diabetes, kidney function, urinary diagnostics, liver function, blood coagulation, blood count, therapeutic drug monitoring and drugs of abuse screening.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Overview of the possibilities and limitations in clinical laboratory diagnostics. Indications and methods of everyday parameters are known.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Introduction into medical laboratory diagnostics: immunochemical methods, diagnostics of inflammation, acute myocardial infarction, lipid metabolism, diabetes, kidney function and urinary diagnostics, blood coagulation, blood count, therapeutic drug monitoring, drugs of abuse screening, common diagnostics of liver diseases, point-of-care diagnostics.</td>
<td></td>
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</tr>
<tr>
<td>535-0440-AAL</td>
<td>Quality Management in Pharmaceutical Business</td>
<td>E-</td>
<td>1 credit</td>
<td>2R</td>
<td>A. Sterchi</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>The students know the relevance and the role of quality assurance measures to assure quality, efficacy and safety of drugs. The students know the most important Swiss regulations, including the associated European regulations, which are relevant from a quality assurance point of view and they are able to interpret the content of this regulations.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language &quot;R&quot;.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>From &quot;Statistics for research&quot; (online)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ch 1: The Role of Statistics</td>
<td></td>
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<tr>
<td></td>
<td>Ch 2: Populations, Samples, and Probability Distributions</td>
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<tr>
<td></td>
<td>Ch 3: Binomial Distributions</td>
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<tr>
<td></td>
<td>Ch 6: Sampling Distribution of Averages</td>
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<tr>
<td></td>
<td>Ch 7: Normal Distributions</td>
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<tr>
<td></td>
<td>Ch 8: Student's t Distribution</td>
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<tr>
<td></td>
<td>Ch 9: Distributions of Two Variables</td>
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</tr>
<tr>
<td></td>
<td>From &quot;Introductory Statistics with R (online)&quot;</td>
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</tr>
<tr>
<td></td>
<td>Ch 1: Basics</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Ch 2: The R Environment</td>
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<tr>
<td></td>
<td>Ch 3: Probability and distributions</td>
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<tr>
<td></td>
<td>Ch 4: Descriptive statistics and tables</td>
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<tr>
<td></td>
<td>Ch 5: One- and two-sample tests</td>
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</tr>
<tr>
<td></td>
<td>Ch 6: Regression and correlation</td>
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</tr>
<tr>
<td>Literature</td>
<td>&quot;Statistics for research&quot; by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435</td>
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<td></td>
<td>From within the ETH, this book is freely available online under: <a href="http://onlinelibrary.wiley.com/book/10.1002/0471477435">http://onlinelibrary.wiley.com/book/10.1002/0471477435</a></td>
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<td></td>
<td>From within the ETH, this book is freely available online under: <a href="http://www.springerlink.com/content/m17578/">http://www.springerlink.com/content/m17578/</a></td>
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</tr>
<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>E-</td>
<td>4 credits</td>
<td>9R</td>
<td>M. Kalisch</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language &quot;R&quot;.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>From &quot;Statistics for research&quot; (online)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Ch 1: Basics</td>
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<td>Ch 2: The R Environment</td>
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<td>Ch 5: One- and two-sample tests</td>
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</tr>
<tr>
<td>551-0110-AAL</td>
<td>Fundamentals of Biology II: Microbiology</td>
<td>E-</td>
<td>2 credits</td>
<td>2R</td>
<td>J. Vorholt-Zambelli</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Structure, function, genetics of prokaryotic microorganisms and fungi.</td>
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<tr>
<td>Lecture notes</td>
<td>none</td>
<td></td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>none</td>
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</tbody>
</table>

551-0103-AAL | Fundamentals of Biology II: Cell Biology        | E-   | 5 credits | 11R   | U. Kutay, Y. Barral, G. Schertler, U. Suter, S. Werner |
|            | Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. |      |       |       |                                  |

Abstract

The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Objective

The goal of this course is to provide students with a wide general understanding in cell biology. With this material as a foundation, students have enough of a cell biological basis to begin their specialization not only in cell biology but also in related fields such as biochemistry, microbiology, pharmacological sciences, molecular biology, and others.

Content

The focus is animal cells and the development of multicellular organisms with a clear emphasis on the molecular basis of cellular structures and phenomena. The topics include biological membranes, the cytoskeleton, protein sorting, energy metabolism, cell cycle and division, viruses, extracellular matrix, cell signaling, embryonic development and cancer research.

Literature


Topic/Lecturer/Chapter/Pages:

- Analyzing cells & molecules / Gebhard Schertler/8/ 439-463;
- Membrane structure / Gebhard Schertler/10/ 565-595;
- Compartmental and Sorting / Ulrike Kutay/12-14/ 641-694/755-758/782-783/315-320/325 -333/Table 6-2/Figure6-20, 6-21, 6-32, 6-34;
- Intracellular Membrane Traffic / Ulrike Kutay/13/695-752;
- The Cytoskeleton / Ulrike Kutay/ 16/ 889 - 948 (only the essentials);
- Membrane Transport of Small Molecules and the Electrical Properties of Membranes /Sabine Werner/11/597 - 633;
- Mechanisms of Cell Communication / Sabine Werner/15/813-876;
- Cancer/ Sabine Werner/20/1091-1141;
- Cell Junctions and Extracellular Matrix/Ueli Suter / 1035-1081;
- Stem Cells and Tissue Renewal/Ueli Suter /12/17-1262;
- Development of Multicellular organisms/ Ernst Hafen/ 21/ 1145-1179 /1184-1198/1198-1213;
- Cell Migration/Joao Matos/951-960;
- Cell Death/Joao Matos/1021-1032;

Prerequisites / notice

none

551-1323-AAL Fundamentals of Biology II: Biochemistry and Molecular Biology

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

The course provides an introduction to Biochemistry / Molecular Biology with some emphasis on chemical and biophysical aspects.

Objective

Topics include the structure-function relationship of proteins / nucleic acids, protein folding, enzymatic catalysis, cellular pathways involved in bioenergetics and the biosynthesis and breakdown of amino acids, glycans, nucleotides, fatty acids and phospholipids, and steroids. There will also be a discussion of DNA replication and repair, transcription, and translation.

Lecture notes

none

Literature


Pharmacy Master - Key for Type

O Compulsory
W+ Eligible for credits and recommended
W Eligible for credits

Key for Hours

V lecture
G lecture with exercise
U exercise
S seminar
K colloquium

Key for Hours

P practical/laboratory course
A independent project
D diploma thesis
R revision course / private study

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0101-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
</tbody>
</table>

**Abstract**

Research colloquium

---

**Physics (General Courses) - Key for Type**

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
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</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Physics Bachelor

First Year

Minor Courses

GESS Science in Perspective

First Year Compulsory Courses

Bachelor Studies (Programme Regulations 2021)

First Year Compulsory Courses

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-1261-07L</td>
<td>Analysis I: One Variable</td>
<td>O</td>
<td>10 credits</td>
<td>6V+3U</td>
<td>M. Einsiedler</td>
</tr>
</tbody>
</table>

Abstract
Introduction to the differential and integral calculus in one real variable: fundamentals of mathematical thinking, numbers, sequences, basic point set topology, continuity, differentiable functions, ordinary differential equations, Riemann integration.

Objective
The ability to work with the basics of calculus in a mathematically rigorous way.

Literature
- H. Amann, J. Escher: Analysis I
  https://link.springer.com/book/10.1007/978-3-7643-7756-4
- J. Appell: Analysis in Beispielen und Gegenbeispielen
- R. Courant: Vorlesungen über Differential- und Integralrechnung
- O. Forster: Analysis 1
- H. Heuser: Lehrbuch der Analysis
- K. Königsberger: Analysis 1
  https://link.springer.com/book/10.1007/978-3-642-18490-1
- W. Walter: Analysis 1
- V. Zorich: Mathematical Analysis I (englisch)
- A. Beutelspacher: "Das ist o.B.d.A. trivial"
- H. Schichl, R. Steinbauer: Einführung in das mathematische Arbeiten

402-1701-00L Physics I O 7 credits 4V+2U K. Ensslin

Abstract
This course gives a first introduction to Physics with an emphasis on classical mechanics.

Objective
Acquire knowledge of the basic principles regarding the physics of classical mechanics. Skills in solving physics problems.

252-0847-00L Computer Science O 5 credits 2V+2U R. Sasse, F. O. Friedrich Wicker

Abstract
The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.

Objective
Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens "behind the scenes" when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.

Content
The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.

Lecture notes
English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.

Literature
- Bjørn Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010
- Andrew Koenig and Barbara E. Moo: Accelerated C++, Addison-Wesley, 2000

First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>
| 401-1151-00L Linear Algebra I O 7 credits 4V+2U R. Pink

Abstract

Objective
- Mastering basic concepts of Linear Algebra
- Introduction to mathematical methods
- Basics
- Vectorspaces and linear maps
- Systems of linear equations and matrices
- Determinants
- Endomorphisms and eigenvalues

Bachelor Studies (Programme 2016)

Second and Third Year Compulsory Courses

Examination Block I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2303-00L</td>
<td>Complex Analysis</td>
<td>O</td>
<td>6</td>
<td>3V+2U</td>
<td>T. H. Willwacher</td>
</tr>
<tr>
<td>Abstract</td>
<td>Complex functions of one variable, Cauchy-Riemann equations, Cauchy theorem and integral formula, singularities, residue theorem, index of closed curves, analytic continuation, special functions, conformal mappings, Riemann mapping theorem.</td>
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</tr>
<tr>
<td>Objective</td>
<td>Working knowledge of functions of one complex variables; in particular applications of the residue theorem.</td>
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</tr>
</tbody>
</table>
| Literature  | B. Paika: "An introduction to complex function theory."

Methods of Mathematical Physics I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2333-00L</td>
<td>Methods of Mathematical Physics I</td>
<td>O</td>
<td>6</td>
<td>3V+2U</td>
<td>G. Felder</td>
</tr>
<tr>
<td>Objective</td>
<td>A basic introduction to quantum and atomic physics including optics and statistical physics. The course will focus on the relation of these topics to experimental methods and observations.</td>
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</tr>
<tr>
<td>Content</td>
<td>Einführung in die Quantenphysik: Planck'sche Strahlung (Wärmestrahlung), Photonen, Photoelektrischer Effekt, Thomson und Rutherford Streuung, Compton Streuung, Bohrsche Atommodell, de-Broglie Materiewellen.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Optik/Wellenoptik: Linsen, Abbildungssysteme, Brechung und Fermatsches Prinzip, Beugung, Interferenz, Fabry-Perot, Interferometer, Spektrometer.</td>
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</tr>
<tr>
<td></td>
<td>Quantenmechanik: Dualismus Teilchen-Welle, Wellenfunktionen, Operatoren, Schrödinger-Gleichung, Potentialstufe und Potentialkasten, harmonischer Oszillator</td>
<td></td>
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</tr>
</tbody>
</table>
|             | Literature | M. Alonso, E. J. Finn 
Quantenphysik und Statistische Physik 
R. Oldenbourg Verlag, München 
5. Auflage 
ISBN 978-3-486-71340-4 |      |      |       |                |

Examination Block II

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-2203-01L</td>
<td>Classical Mechanics</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>R. Renner</td>
</tr>
<tr>
<td>Abstract</td>
<td>A conceptual introduction to theoretical physics: Newtonian mechanics, central force problem, oscillations, Lagrangian mechanics, symmetries and conservation laws, spinning top, relativistic space-time structure, particles in an electromagnetic field, Hamiltonian mechanics, canonical transformations, integrable systems, Hamilton-Jacobi equation.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Fundamental understanding of the description of Mechanics in the Lagrangian and Hamiltonian formulation. Detailed understanding of important applications, in particular, the Kepler problem, the physics of rigid bodies (spinning top) and of oscillatory systems.</td>
<td></td>
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</tr>
</tbody>
</table>
Examination Block III

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0205-00L</td>
<td>Quantum Mechanics I</td>
<td>O</td>
<td>10</td>
<td>3V+2U</td>
<td>M. Gaberdiel</td>
</tr>
</tbody>
</table>

Abstract

Objective
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradox and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle, in deutscher Sprache

Literature
- G. Baym, Lectures on Quantum Mechanics
- E. Merzbacher, Quantum Mechanics
- L.I. Schiff, Quantum Mechanics
- R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
- J.J. Sakurai: Modern Quantum Mechanics
- A. Messiah: Quantum Mechanics I
- S. Weinberg: Lectures on Quantum Mechanics

Taught competencies
- Domain A - Subject-specific Competencies: Concepts and Theories - assessed
- Domain B - Method-specific Competencies: Analytical Competencies - assessed

Core Courses
Core Courses in Experimental Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0263-00L</td>
<td>Astrophysics I</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>S. Lilly</td>
</tr>
</tbody>
</table>

Abstract
This introductory course will develop basic concepts in astrophysics as applied to the understanding of the physics of planets, stars, galaxies, and the Universe.

Objective
The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0255-00L</td>
<td>Introduction to Solid State Physics</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>C. Degen</td>
</tr>
</tbody>
</table>

Abstract
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, magnetism, superconductivity.

Objective
Introduction to Solid State Physics.

Content
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, thermal properties of insulators; metals (classical and quantum mechanical description of electronic states, thermal and transport properties of metals); semiconductors (bandstructure and n/p-type doping); magnetism, superconductivity.

Lecture notes
The script will be available on moodle.

Literature
- Ibach & Lüth, Festkörperphysik
- C. Kittel, Festkörperphysik
- Ashcroft & Mermin, Festkörperphysik
- W. Känzig, Kondensierte Materie

Prerequisites / notice
Voraussetzungen: Physik I, II, III wünschenswert

Practical Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0000-01L</td>
<td>Physics Lab 1</td>
<td>O</td>
<td>5</td>
<td>1V+4P</td>
<td>A. Eichler, M. Kroner</td>
</tr>
</tbody>
</table>

Enrollment is only possible under https://www.lehrbetrieb.ethz.ch/laborpрактика. No registration required via myStudies. For further information visit: https://ap.phys.ethz.ch

Only students from 3rd Semester BSc Physics are...
Physics Lab 3

This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills.

Manuals for the individual experiments are available in English.

Students learn to independently perform advanced experiments and document them scientifically correct.

The following aspects are emphasized:
- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

We offer experiments covering the following topics:
Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

Instructions for experiments are available in English.

Prerequisites / notice
From a variety of over 50 experiments, students have to perform 4 experiments covering different topics. The experimental work is complemented by writing a scientific report.

Taught competencies
- Domain A - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies
- Domain B - Method-specific Competencies: Analytical Competencies, Problem-solving
- Domain C - Social Competencies: Communication, Cooperation and Teamwork
- Domain D - Personal Competencies: Adaptability and Flexibility, Creative Thinking, Critical Thinking, Integrity and Work Ethics, Self-direction and Self-management

Proseminars, Experimental and Theoretical Semester Papers

To organise a semester project take contact with one of the instructors.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0210-BSL</td>
<td>Proseminar Theoretical Physics</td>
<td>W</td>
<td>8</td>
<td>4S</td>
<td>Supervisors</td>
</tr>
<tr>
<td>402-0217-BSL</td>
<td>Semester Project in Theoretical Physics</td>
<td>W</td>
<td>8</td>
<td>15A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>402-0215-BSL</td>
<td>Experimental Semester Project in Physics</td>
<td>W</td>
<td>8</td>
<td>15A</td>
<td>Supervisors</td>
</tr>
<tr>
<td>402-0719-BSL</td>
<td>Particle Physics at PSI (Paul Scherrer Institute)</td>
<td>W</td>
<td>8</td>
<td>15P</td>
<td>A. Soter, A. S. Antognini</td>
</tr>
</tbody>
</table>

Objective
Students learn all the different steps it takes to perform a complete particle physics experiment in a small team. They acquire skills to do this themselves in the team, including design, construction, data taking and data analysis.

402-0717-BSL
Particle Physics at CERN
W 8 credits 15P W. Lustermann

Abstract
During the semester break participating students stay for 4 weeks at CERN and perform experimental work relevant to our particle physics projects. Dates to be agreed upon.

402-0340-BSL
Medical Physics
W 8 credits 15P A. J. Lomax, K. P. Prüssmann

Abstract
This laboratory course provides basic training of experimental skills. These are experimental design, implementation, measurement, data analysis and interpretation, as well as error analysis. The experimental work has to be complemented by a concise written report, which trains the scientific writing skills.

Objective
Students learn, by doing, the needed skills to perform a small particle physics experiment: setup, problem solving, data taking, analysis, interpretation and presentation in a written report of publication quality.

402-0340-BSL
Medical Physics
W 8 credits 15P A. J. Lomax, K. P. Prüssmann

Abstract
In agreement with the lecturers a semester paper in the context of the topics discussed in the lectures can be written.

402-0000-10L
Physics Lab 4
W 8 credits 15P M. Donegà, S. Gvasaliya

Abstract
Enrol at most once in the course of the Bachelor programme!

Objective
Students learn to independently perform advanced experiments and document them scientifically correct.

Content
We offer experiments covering the following topics:
Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

402-0351-00L
Astronomy
Z 2 credits 2V S. P. Quanz

Abstract
An overview of important topics in modern astronomy: planets, sun, stars, milky way, galaxies, and cosmology

Objective
This lecture gives a general introduction to main topics in modern astronomy. The lecture provides a basis for the more advanced lectures in astrophysics.

401-1511-00L
Geometry
Z 3 credits 2V+1U T. Ilmanen

Objective
Students are required to attend a safety lecture on the first day of the course and pass the corresponding online moodle-test before being allowed to access the laboratory rooms and perform the experiments.

The following aspects are emphasized:
- understanding complicated physical phenomena
- structured approach to experiments with complex instruments
- various practical aspects of experimenting and determining uncertainties
- learning the relevant statistical methods for data analysis
- interpretation of measurements and uncertainties
- describing the experiments and the results in a scientifically proper manner, in direct analogy to publishing
- ethical aspects of experimental research and scientific communication

Content
We offer experiments covering the following topics:
Basic topics from mechanics, optics, thermodynamics, electromagnetism and electronics; as well as central topics from nuclear and particle physics, quantum electronics, quantum mechanics, solid state physics and astrophysics.

Prerequisites / notice
From a variety of over 50 experiments, students have to perform 4 experiments covering different topics. The experimental work is complemented by writing a scientific report.

Lecture notes
Kopien der Präsentationen werde zur Verfügung gestellt.

Literature
Der Neue Kosmos. A. Unsöld, B. Baschek, Springer
Oder sonstige Grundlehrbücher zur Astronomie.

GESS Science in Perspective

Science in Perspective
see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-PHYS.

Language Courses
see Science in Perspective: Language Courses ETH/UZH

Additional Courses, Seminars and Colloquia
First or Second Year Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0351-00L</td>
<td>Astronomy</td>
<td>Z</td>
<td>2</td>
<td>2V</td>
<td>S. P. Quanz</td>
</tr>
<tr>
<td>Abstract</td>
<td>An overview of important topics in modern astronomy: planets, sun, stars, milky way, galaxies, and cosmology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>This lecture gives a general introduction to main topics in modern astronomy. The lecture provides a basis for the more advanced lectures in astrophysics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Planeten, Sonne, Sterne, Milchstrasse, Galaxien und Kosmologie.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Kopien der Präsentationen werde zur Verfügung gestellt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Der Neue Kosmos. A. Unsöld, B. Baschek, Springer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oder sonstige Grundlehbücher zur Astronomie.</td>
<td></td>
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</tbody>
</table>

401-1511-00L
Geometry
Z 3 credits 2V+1U T. Ilmanen
Abstract  Symmetry, metrics, and groups

Objective  Understand geometric symmetry

Content  Platonic solids, polytopes, crystals, Euclidean space, hyperbolic space, the sphere, metric spaces, their metric properties and symmetry groups -- as far as possible.

Lecture notes  See course website

Literature  See course website

Taught competencies
- Domain A - Subject-specific Competencies  Concepts and Theories  assessed
- Domain B - Method-specific Competencies  Analytical Competencies  assessed
- Domain D - Personal Competencies  Critical Thinking  assessed

Additional Courses (from Second Year Mathematics Bachelor)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2003-00L</td>
<td>Algebra I</td>
<td>Z</td>
<td>7</td>
<td>4V+2U</td>
<td>L. Halbeisen</td>
</tr>
</tbody>
</table>

Abstract  The two-semester course Algebra I / Algebra II is offered for the last time in its current version in the Autumn Semester 2021 / Spring Semester 2022.

Objective  Introduction to basic notions and results of group, ring and field theory.

Content  Group Theory: basic notions and examples of groups, subgroups, factor groups, homomorphisms, group actions, Sylow theorems, applications

- Ring Theory: basic notions and examples of rings, ring homomorphisms, ideals, factor rings, euclidean rings, principal ideal domains, factorial rings, applications

- Field Theory: basic notions and examples of fields, field extensions, algebraic extensions, applications

Literature  Karpfinger-Meyberg: Algebra, Spektrum Verlag
S. Bosch: Algebra, Springer Verlag
B.L. van der Waerden: Algebra I und II, Springer Verlag
S. Lang, Algebra, Springer Verlag
A. Knapp: Basic Algebra, Springer Verlag
J. Rotman, “Advanced modern algebra, 3rd edition, part 1”
http://bookstore.ams.org/gsm-165/
J.F. Humphreys: A Course in Group Theory (Oxford University Press)
G. Smith and O. Tabachnikova: Topics in Group Theory (Springer-Verlag)
M. Artin: Algebra (Birkhaeuser Verlag)

Seminars and Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0101-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
<tr>
<td>402-0800-00L</td>
<td>The Zurich Theoretical Physics Colloquium</td>
<td>E-</td>
<td>0</td>
<td>1K</td>
<td>J. Renes, University lecturers</td>
</tr>
</tbody>
</table>

Objective  The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0501-00L</td>
<td>Solid State Physics</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>A. Zheludev, C. Degen, K. Ensslin, D. Pescia, M. Sigrist, A. Wallraf</td>
</tr>
<tr>
<td>402-0600-00L</td>
<td>Nuclear and Particle Physics with Applications</td>
<td>E-</td>
<td>0</td>
<td>2S</td>
<td>A. Rubbia, G. Dissertori, K. S. Kirch, R. Walny</td>
</tr>
<tr>
<td>402-0893-00L</td>
<td>Particle Physics Seminar</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>T. K. Gehrmann</td>
</tr>
</tbody>
</table>

Abstract  Occasionally, talks may be delivered in German.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0700-00L</td>
<td>Seminar in Elementary Particle Physics</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>M. Spira, University lecturers</td>
</tr>
</tbody>
</table>

Abstract  Special Students UZH must book the modul PHY463 directly at UZH.

Objective  Stay informed about current research results in elementary particle physics.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0746-00L</td>
<td>Seminar: Particle and Astrophysics (Aktuelles aus der E-Teilchen- und Astrophysik)</td>
<td>E-</td>
<td>0</td>
<td>1S</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

Abstract  Occasionally, talks may be delivered in German.
In Seminarvorträgen werden aktuelle Fragestellungen aus der Teilchenphysik vom theoretischen und experimentellen Standpunkt aus diskutiert. Besonders wichtig erscheint uns der Bezug zu den eigenen Forschungsmöglichkeiten am PSI, CERN und DESY.

**IPA Colloquium**
- E- 0 credits
- 1S
- A. Biland, A. Refregier, H. M. Schmid, further lecturers

**Mesoscopic Systems**
- E- 0 credits
- 1S
- T. M. Ihn

**Seminar on Biomedical Magnetic Resonance**
- E- 0 credits
- 1S
- K. P. Prüssmann, S. Kozerke, M. Weiger Senften

**Neuroinformatics - Colloquia (University of Zurich)**
- No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
- UZH Module Code: INI701
- S.-C. Liu, R. Hahnloser, V. Mante

**Recent Research Highlights in Astrophysics (University of Zurich)**
- University lecturers

**Selection of Higher Semester Courses**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0811-00L</td>
<td>Programming Techniques for Scientific Simulations I</td>
<td>W</td>
<td>5</td>
<td>4G</td>
<td>R. Käppeli</td>
</tr>
<tr>
<td>402-0713-00L</td>
<td>Astro-Particle Physics I</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>A. Biland</td>
</tr>
<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

*Content*  
*Objective*  
*Abstract*  
*Literature*  
*Lecture notes*
Why is energy important for life and our society?

Content

Physical basics of energy, thermodynamics and life. Introduction to self-organisation, and systems. Energy and making use of it - a short history and overview on energy technologies
Coal, oil and natural gas – fossil fuels
Hydro, Wind & Solarpower (Geothermal- and Tidal power) – the quest for renewable energy
Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
Breeding and Nuclear Fusion – can it work at all?
Energy storage – available technologies and a technology outlook
Climate change, decarbonisation – how much time do we have?
Energy efficiency, recycling and other resource conservation measures
Energy systems – how everything can play together
Buildings and Mobility – new technologies, new Ways of life?
Life cycle assessment of Energy Technologies – problems and possibilities
Economics of energy, learning curves, technology assessments and Innovation.

The energy transition and decarbonization – How is your 2040, 2050?

Prerequisites / notice

Lecture notes

Web page:
http://thp-ix2.ethz.ch/energy21/index.html

Literature

The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Smil, 2018

Introduction to the most important concepts of superconductivity both on phenomenological and microscopic level, including experimental and theoretical aspects.

The preceding attendance of the scheduled lecture courses "Introduction to Solid State Physics" and "Quantum Mechanics I" are mandatory. The lectures "Quantum Mechanics II" and "Solid State Theory" provide the most optimal conditions to follow this course.

V. V. Schmidt "The Physics of Superconductors"
A. A. Abrikosov "Fundamentals of the Theory of Metals"
P. G. de Gennes "Superconductivity Of Metals And Alloys"
A. A. Abrikosov "Fundamentals of the Theory of Metals"
V. V. Schmidt "The Physics of Superconductors"

Prerequisites / notice

The energy transition and decarbonization – How is your 2040, 2050?

Lecture notes

Distributed via moodle.

Literature

Nielsen and Chuang, Quantum Information and Computation
Preskill, Lecture Notes on Quantum Computation
Wilde, Quantum Information Theory
Watrous, The Theory of Quantum Information

Abstract

The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

Objective

By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

Content

Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties.
Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

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The energy transition and decarbonization – How is your 2040, 2050?

Lecture notes

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Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties.
Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

The energy transition and decarbonization – How is your 2040, 2050?

Lecture notes

Distributed via moodle.

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Preskill, Lecture Notes on Quantum Computation
Wilde, Quantum Information Theory
Watrous, The Theory of Quantum Information

Abstract

The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

Objective

By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

Content

Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties.
Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

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The energy transition and decarbonization – How is your 2040, 2050?

Lecture notes

Distributed via moodle.

Literature

Nielsen and Chuang, Quantum Information and Computation
Preskill, Lecture Notes on Quantum Computation
Wilde, Quantum Information Theory
Watrous, The Theory of Quantum Information

Abstract

The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

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The energy transition and decarbonization – How is your 2040, 2050?
The course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurons. Feedforward and recurrent networks will be discussed in the context of the rules governing the formation of nerve connections and synaptic structures. Simple models of computation, learning, and communication through neuronal circuits arise in the context of the rules governing the formation of nerve connections and synaptic structures. Simple models of computation, learning, and regulation of the nervous system. Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocularities of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the ensembles and challenges that we all face in taking on the major 21st century problem and how each discipline can contribute to discovering solutions.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue’s anisotropies of biopsies.

Abstract

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be explained. Some artificial systems (robot, chip) are presented.

Objective

Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocularities of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the ensembles and challenges that we all face in taking on the major 21st century problem and how each discipline can contribute to discovering solutions.

Content

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401-3531-00L Differential Geometry I

W 10 credits

At most one of the three course units (Bachelor Core Courses)

W 6 credits

401-3461-00L Functional Analysis I

401-3531-00L Differential Geometry I

401-3601-00L Probability Theory

4V+1U J. Serra

W. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens

Abstract

Introduction to differential geometry and differential topology. Contents: Curves, (hyper-)surfaces in R^n, geodesics, curvature, Theorema Egregium, Theorem of Gauss-Bonnet. Hyperbolic space. Differentiable manifolds, immersions and embeddings, Sard's Theorem, mapping degree and intersection number, vector bundles, vector fields and flows, differential forms. This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.
Baire category; Banach and Hilbert spaces, bounded linear operators; basic principles: Uniform boundedness, open mapping/closed graph theorem, Hahn-Banach; convexity; dual spaces; weak and weak* topologies; Banach-Alaoglu; reflexive spaces; compact operators and Fredholm theory; closed range theorem; spectral theory of self-adjoint operators in Hilbert spaces.

Objective
Acquire a good degree of fluency with the fundamental concepts and tools belonging to the realm of linear Functional Analysis, with special emphasis on the geometric structure of Banach and Hilbert spaces, and on the basic properties of linear maps.

Literature
Recommended references include the following:


Prerequisites / notice
Solid background on the content of all Mathematics courses of the first two years of the undergraduate curriculum at ETH (most remarkably: fluency with topology and measure theory, in part. Lebesgue integration and L^p spaces).

401-3601-00L Probability Theory
At most one of the three course units (Bachelor Core Courses)
401-3461-00L Functional Analysis I
401-3531-00L Differential Geometry I
401-3601-00L Probability Theory
can be recognised for the Master's degree in Mathematics or Applied Mathematics. In this case, you cannot change the category assignment by yourself in myStudies but must take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having received the credits.

Abstract
Basics of probability theory and the theory of stochastic processes in discrete time

Objective
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory,
- series of independent random variables, law of large numbers, weak convergence, characteristic functions,
- central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Content
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Lecture notes
will be available in electronic form.

Literature
H. Bauer, Probability Theory, de Gruyter 1996
J. Jacod and P. Protter, Probability essentials, Springer 2004
A. Klenke, Wahrscheinlichkeitstheorie, Springer 2006
D. Williams, Probability with martingales, Cambridge University Press 1991

401-3621-00L Fundamentals of Mathematical Statistics
The course covers the basics of inferential statistics.

402-0247-00L Electronics for Physicists I (Analogue)
Number of participants limited to 40.

Abstract
Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology

Objective
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

Content
Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC's and DAC's, introduction in CMOS technology. Practical exercices in small groups to the above themes complement the lectures.

Prerequisites / notice
no prior knowledge in electronics is required

Taught competencies
Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Problem-solving
- Cooperation and Teamwork

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking

402-0010-00L Basics of Computing Environments for Scientists
Enrollment is only possible under
Introduction:
- IT at D-PHYS (Herzog): 29.9. 1300
- IT at D-PHYS 2. Termin (Herzog): 7.10. 1300

Modules:
- Linux Basics I (Müller): 13.10. 1300
- Linux Basics II (Müller): 20.10. 1300
- Python Ecosystem I (Becker): 27.10. 1300
- Python Ecosystem II (Becker): 3.11. 1300
- System Aspects (Herzog): 10.11. 1300

Abstract
Introduce IT services at D-PHYS and offer modules covering IT-related topics for scientists.

Objective
The "IT at D-PHYS" introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department. The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.

The "Linux Basics" modules offer an introduction to the Linux landscape and show how to work on the shell by using command line tools. The first part provides a basic understanding of Linux systems and their components. It introduces commands essential to working with local and remote machines. The second part focuses on more advanced tools and workflows and provides guidelines to scripting, automation and customization.

The "Python Ecosystem" modules present various aspects on the ecosystem around Python, without covering the programming language itself. The first part focuses on getting ready to run code. It discusses the management of Python interpreters, packages and virtual environments. The second part presents tools for writing code. From development environments (IDE, Jupyter), over code formatters and linters, to skimming selected concepts (string formatting, regular expressions).

The "System Aspects module" deals with the hardware-related side of scientific computing. To get the best performance out of your scientific code, you have to be aware of the underlying hardware and adapt to it.

Use the dedicated web page https://www.lehrbetrieb.ethz.ch/laborpraktika to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to https://compenv.phys.ethz.ch for the detailed contents.

Content
- IT at D-PHYS (IT service providers and IT services at D-PHYS)

modules:
- Linux Basics I (system components, basic shell usage)
- Linux Basics II (advanced tools, scripting)
- Python Ecosystem I (interpreters, packages, virtual environments)
- Python Ecosystem II (development environments, formatter and linter, string formatting, regexp)
- System Aspects (how the hardware affects your scientific code and vice versa)

Physics Bachelor - Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
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<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Z</th>
<th>Courses outside the curriculum</th>
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<tbody>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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<tr>
<td>O</td>
<td>Compulsory</td>
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Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<tr>
<th>P</th>
<th>practical/laboratory course</th>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
### Educational Science

**General course offerings in the category Educational Science are listed under “Programme: Educational Science for Teaching Diploma and TC”**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>E. Stern</td>
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<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs “Teaching Diploma” or “Teaching Certificate”. It is about learning in childhood and adolescence.</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
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<td><strong>Objective</strong></td>
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<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an advantage of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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<td><strong>Content</strong></td>
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<td>Thematische Schwerpunkte:</td>
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<td>Lernen als Verhaltensänderung und als Informationsverarbeitung:</td>
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<td>Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen: Intelligenztheorien, Geschlechtsunterschiede beim Lernen</td>
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<td>Lernformen:</td>
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<td><strong>Lecture notes</strong></td>
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<td><strong>Literature</strong></td>
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<tr>
<td></td>
<td>1) Marcus Hasselhorn &amp; Andreas Goid (2006): Pädagogische Psychologie:</td>
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<td>Erfolgreiches Lernen und Lehren, Stuttgart; Kohlhammer. 2) Jeanne</td>
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<td></td>
<td>Hall 3; Greutmann, Saalbach, Stern (Hrsg.), (2020): Professionalen</td>
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<tr>
<td></td>
<td>Handlungswissen für Lehrerinnen und Lehrer. Kohlhammer Verlag</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<td>This lecture is only apt for students who intend to enrol in the programs “Lehrdiplom” or “Didaktisches Zertifikat”. It is about learning in childhood and adolescence.</td>
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| 851-0240-22L | Coping with Psychosocial Demands of Teaching (EW4 W DZ)              |       | 2 credits | 3S    | U. Markwalder, S. Maurer,  |
|              | **Number of participants limited to 20.**                           |       |           |       | S. Peteranderf-Rüschoff    |
|              | **Abstract**                                                         |       |           |       |                            |
|              | In this class, students will learn concepts and skills for coping with psychosocial demands of teaching. |       |           |       |                            |
|              | (1) They know relevant rules of conversation and conflict management and are able to apply them in an appropriate way in the school context (e.g. in parental talks). |       |           |       |                            |
|              | (2) They know core aspects of classroom management and know how to apply it concretely (e.g. promoting a positive learning atmosphere, avoiding disciplinary difficulties) and they are aware of possible contacts (e.g. illegal or psychological services). |       |           |       |                            |
| 851-0242-06L | Cognitively Activating Instructions in MINT Subjects (W)            |       | 2 credits | 2S    | R. Schumacher              |
|              | **Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).** |       |           |       |                            |
|              | This course unit can only be enrolled after successful participation in, or during enrollment in the course “Human Learning (EW 1)” |       |           |       |                            |
|              | **Abstract**                                                         |       |           |       |                            |
|              | This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance. |       |           |       |                            |
|              | **Objective**                                                        |       |           |       |                            |
|              | - Get to know cognitively activating instructions in MINT subjects    |       |           |       |                            |
|              | - Get information about recent literature on learning and instruction |       |           |       |                            |
|              | **Prerequisites / notice**                                            |       |           |       |                            |
|              | Für eine reibungslose Semesterplanung wird um frühe Anmeldung und persönliches Erscheinem zum ersten Lehrveranstaltungstermin ersucht. |       |           |       |                            |

| 851-0242-07L | Human Intelligence                                                   |       | 1 credit  | 1S    | E. Stern                  |
|              | **Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).** |       |           |       |                            |
|              | Number of participants limited to 30.                                |       |           |       |                            |
|              | This course unit can only be enrolled after successful participation in, or during enrollment in the course “Human Learning (EW 1)” |       |           |       |                            |
|              | **Abstract**                                                         |       |           |       |                            |
|              | The focus will be on the book “Intelligenz: Grosse Unterschiede und ihre Folgen” by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed. |       |           |       |                            |
|              | **Objective**                                                        |       |           |       |                            |
|              | - Understanding of research methods used in the empirical human sciences |       |           |       |                            |
|              | - Getting to know intelligence tests                                 |       |           |       |                            |
|              | - Understanding findings relevant for education                      |       |           |       |                            |

| 851-0242-08L | Research Methods in Educational Science                             |       | 1 credit  | 2S    | P. Edelsbrunner, T. Braas,  |
|              | **Number of participants limited to 30.**                           |       |           |       | C. M. Thurn                |
|              | This course unit can only be enrolled after successful participation in, or during enrollment in the course “Human Learning (EW 1)” |       |           |       |                            |
### Gender Issues In Education and STEM

**ECTS:** 9P  
**Type:** Gender Issues In Education and STEM  
**Content:** Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them. The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

**Prerequisites / notice:** Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

### Subject Didactics and Professional Training

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0910-00L</td>
<td>Physics Didactics I: Special Didactics of Physics Teaching</td>
<td>O</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Mohr</td>
</tr>
<tr>
<td>402-0915-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>4 credits</td>
<td>9P</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>

**Objective**
- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues.
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher's work.

**Content**
- To understand research methods used in the empirical educational sciences
- To critically examine empirical evidence from scientific journals and media
- To understand and critically evaluate recent findings from the empirical educational sciences

**Abstract**
- Literature from the learning sciences is critically discussed with a focus on research methods.
- At the first meeting, working groups will be assembled and meetings with those will be set up.
- In the small groups students will write critical essays about the read literatureug. At the third meeting, we will discuss the essays and develop research questions in group work.

**Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).**

**Prerequisite:** students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

**Notice:** Enrolment to this course unit only possible at ETH. No enrolment to module 090Phy1 at UZH. Please mind the ETH enrolment deadlines for UZH enrolment to module 090Phy1 at UZH.

**Further information is available from the lecturer via email:** mohrm@ethz.ch

**Simultaneous enrolment in Introductory Internship Physics - course 402-0920-00L - is compulsory for Teaching Diploma Physic**

**Information for UZH students:**
- Enrolment to this course unit only possible at ETH. No enrolment to module 090Phy1 at UZH.
- Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html
- Simultaneous enrolment in Introductory Internship Physics - course 402-0920-00L - is compulsory for Teaching Diploma Physic

**Objective**
- Die Studierenden verfügen über fachdidaktisches Grundwissen für den Physikunterricht an einer Mittelschule. Sie können eigene Lektionen unter Berücksichtigung der vielfältigen Rahmenbedingungen planen, durchführen und evaluieren. Sie reflektieren ihren Unterricht und sind bestrebt, ihn didaktisch und pädagogisch weiter zu entwickeln.
- Die Studierenden kennen die Einsatzmöglichkeiten, Chancen und Schwierigkeiten verschiedener Unterrichtsmethoden und Hilfsmittel. Sie können die Eignung von Unterrichtsformen im Hinblick auf eine Lernsituation beurteilen. Sie bemühen sich in ihrem Unterricht, geeignete Methoden und Medien angesagt an die Klasse und das Thema einzusetzen.

**Content**
- Themenbezogene Schwerpunkte
- Fachspezifisches: Sachstrukturen der gängigen Unterrichtsthemen, Alltagsbezüge, Fehlvorstellungen, Demonstrations- und Schülerexperimente, Arbeitsmittel zu physikalischen Themen des Grundlagen- und Schwerpunktsunterrichts
- Einsatz verschiedener Unterrichtsmaterialien: Experimente, Computer, Taschenrechner, Video, Simulation
- Unterrichtsformen: Lernaufgabe, Werkstatt, Puzzle, Projekt, Gruppenarbeit, Praktikum
- Lernformen
- Interaktive Lehr-Lernveranstaltung mit Vorträgen und Demonstrationen des Dozenten, studentischer Einzel- und Kleingruppenarbeit, kurzen Präsentationen der Studierenden, Verleihung der Inhalte durch Bearbeitung von Aufträgen ausserhalb der Kontaktstunden

**Lecture notes**
- Folien und weitere Unterlagen werden zur Verfügung gestellt

**Literature**
- wird während der Veranstaltung mitgeteilt

**Prerequisites / notice**
- Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen

**Number**
- 402-0910-00L
- 402-0915-00L

**Type**
- Physics Didactics I: Special Didactics of Physics Teaching
- Teaching Internship Physics for TC

**ECTS**
- 4 credits

**Hours**
- 3G

**Lecturers**
- M. Mohr

**Number of participants limited to 30.**
**Examination Lessons are to be repeated.**

**Abstract**
Students apply the insights, abilities and skills they have acquired within the context of an educational institution. They observe 10 lessons and teach 20 lessons independently. Two of them are assessed as Examination Lessons.

**Objective**
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics for their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They learn the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils’ work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

**Content**

Die Themen für die beiden Prüfungslektionen am Schluss des Praktikums erfahren die Studierenden in der Regel eine Woche vor dem Prüfungstermin. Sie erstellen eine Vorbereitung gemäss Anleitung und reichen sie bis am Vortrag um 12 Uhr den beiden Prüfungsexperten (Fachdidaktiker/-in, Departementsvertreter/-in) ein. Die gehaltenen Lektionen werden kriteriumsbasiert beurteilt. Die Beurteilung umfasst auch die schriftliche Vorbereitung und eine mündliche Reflexion des Kandidaten/der Kandidatin über die gehaltenen Lektionen im Rahmen eines kurzen Kolloquiums.

**Lecture notes**
Wird von der Praktikumslehrperson bestimmt.

**Literature**
Dokument: schriftliche Vorbereitung für Prüfungslektionen.

**402-0917-00L**
**Mentored Work Subject Didactics Physics A**

**Abstract**
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Objective**
- The objective is for the students:
  - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
  - to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

**Content**
Thematic Focus
The topics of the mentored work are mostly chosen from the high school curriculum.

**Methods**
With the help of the mentor the students individually work on a topic and write a thesis about it.

**Lecture notes**
http://www.fachdidaktik.physik.ethz.ch/unterlagen.html

**Prerequisites / notice**
The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| | Techniques and Technologies | assessed |
| | Decision-making | assessed |
| | Problem-solving | assessed |
| | Project Management | assessed |
| | Cooperation and Teamwork | assessed |
| | Customer Orientation | assessed |
| | Leadership and Responsibility | assessed |
| | Self-presentation and Social Influence | assessed |
| | Sensitivity to Diversity | assessed |
| | Negotiation | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |
| | Self-direction and Self-management | assessed |

**Specialized Courses in Respective Subject with Educational Focus**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0737-00L</td>
<td><strong>Energy and Sustainability in the 21st Century (Part I)</strong></td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

**Objective**
Why is energy important for life and our society?
How did energy use change over time? Which effects did these changes have on the environment?
What are the physical basics of energy technologies?
When, why and how did technology and science of energy come together?
What are the limits and benefits of all the various energy technologies?
How can different energy technologies be compared?
Can we understand the changes in the current energy systems?
How will the energy systems of the future look like?
How fast can we and should we alter the current energy transition?
Which could be the overall guide lines for a working energy system of the future?
Practice in the explanation of complex topics in physics as the core competence of the teaching profession assessed.

We explore how traditional and new physics concepts and achievements make their way into today's ubiquitous high-tech gadget: the Web page.

Examples: network topology and scratch proof glass, spin-orbit coupling - brighter displays, GPS Analytical Competencies

Choice of topic by individual arrangement

Students recognize and appreciate the enormous impact "physics" has on today's high tech world. Abstract concepts, old and recent, encountered in the lectures are implemented and present all around us.

The presentation material and original literature will be distributed weekly.

Mentored Work Specialised Courses in Physics with an Educational Focus A

Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for TC and Teaching Diploma. Objective

Practice in the explanation of complex topics in physics as the core competence of the teaching profession Improvement of the physics education by providing attractive recent topics with regard to future curricular decisions and the public view of physics

Content

Choice of topic by individual arrangement

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories assessed

Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed

Decision-making assessed

Problem-solving assessed

Domain C - Social Competencies

Communication assessed

Cooperation and Teamwork assessed

Customer Orientation assessed

Leadership and Responsibility assessed

Self-presentation and Social Influence assessed

Sensitivity to Diversity assessed

Negotiation assessed

Domain D - Personal Competencies

Adaptability and Flexibility assessed

Creative Thinking assessed

Critical Thinking assessed

Integrity and Work Ethics assessed

Self-awareness and Self-reflection assessed

Self-direction and Self-management assessed

Physics in the Smartphone

Does not take place this semester.

Abstract

Physics in today's high-tech smartphone. Examples: network topology and scratch proof glass, spin-orbit coupling - brighter displays, GPS and general theory of relativity, electromagnetic response of matter (transparent metals for displays, GPS signal propagation), light-field cameras, CCD and CMOS light sensors, physics stops Moore's law, meta-materials for antennas, MEMS sensor physics, etc.

Objective

Students recognize and appreciate the enormous impact "physics" has on today's high tech world. Abstract concepts, old and recent, encountered in the lectures are implemented and present all around us.

Students are actively involved in the preparation and presentation of the topics, and thus acquire valuable professional skills.

Content

We explore how traditional and new physics concepts and achievements make their way into today's ubiquitous high-tech gadget: the smartphone. Examples of topics include: network topology and scratch proof Gorilla glass, spin-orbit coupling makes for four times brighter displays, electromagnetic response of matter (transparent metals for displays, GPS signal propagation in the atmosphere), light-field cameras replacing CCD and CMOS light sensors, physical limitations to IC scaling: the end of "Moore's law", meta-materials for antennas, physics of the various MEMS sensors, etc., etc., etc.

Lecture notes

The presentation material and original literature will be distributed weekly.

Basic physics lectures and introduction to solid state physics are expected.

This is a "3 hour" course, with two hours set for <tba>, and the third one to be set at the beginning of the semester.

An introductory event is planned in the first week of the term on Wednesday, September 19th - 17:45 in the room HIT K51. In this meeting we will fix the time of the usual lecture and we will distribute the topics for the presentations during the term. The tutors will briefly present each topic.

### 402-0247-00L Electronics for Physicists I (Analogue)

**W** 4 credits  **2V+2P**  G. Bison, W. Erdmann

#### Abstract
Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology.

#### Objective
The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

#### Content
- Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC's and DAC's, introduction in CMOS technology.
- Practical exercises in small groups to the above themes complement the lectures.

#### Prerequisites / notice
- no prior knowledge in electronics is required

#### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>Techniques and Technologies</th>
<th>not assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Problem-solving</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Cooperation and Teamwork</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td></td>
<td>not assessed</td>
</tr>
</tbody>
</table>

#### Taught competencies
- not assessed

#### Key for Type

<table>
<thead>
<tr>
<th>W+</th>
<th>Eligible for credits and recommended</th>
<th>Z</th>
<th>Courses outside the curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>O</td>
<td>Compulsory</td>
</tr>
</tbody>
</table>

#### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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</table>

#### ECTS
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
## Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects ■ W</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>This seminar focuses on teaching units in chemistry, physics and mathematics that have been developed at the MINT Learning Center of the ETH Zurich. In the first meeting, the mission of the MINT Learning Center will be communicated. Furthermore, in groups of two, the students will intensively work on, refine and optimize a teaching unit following a goal set in advance.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- Get to know cognitively activating instructions in MINT subjects</td>
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<td></td>
<td>- Get information about recent literature on learning and instruction</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td>Für eine reibungsfreie Semesterplanung wird um frühe Anmeldung und persönliches Erscheinen zum ersten Lehrveranstaltungstermin ersucht.</td>
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<tr>
<td>851-0242-07L</td>
<td>Human Intelligence ■ W</td>
<td>W</td>
<td>1</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td></td>
<td>Number of participants limited to 30.</td>
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<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The focus will be on the book &quot;Intelligenz: Grosse Unterschiede und ihre Folgen&quot; by Stern and Neubauer. Participation at the first meeting is obligatory. It is required that all participants read the complete book. Furthermore, in two meetings of 90 minutes, concept papers developed in small groups (5 - 10 students) will be discussed.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<td></td>
<td>- Understanding research methods used in the empirical human sciences</td>
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<td>- Getting to know intelligence tests</td>
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<td></td>
<td>- Understanding findings relevant for education</td>
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<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science ■ W</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas,</td>
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<td></td>
<td>Number of participants limited to 30.</td>
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<td></td>
<td></td>
<td>C. M. Thurn</td>
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<tr>
<td></td>
<td>This course unit can only be enrolled after successful participation in, or during enrollment in the course &quot;Human Learning (EW 1)&quot;.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Literature from the learning sciences is critically discussed with a focus on research methods.</td>
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<td></td>
<td>At the first meeting, working groups will be assembled and meetings with those will be set up.</td>
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<td>In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- Understand research methods used in the empirical educational sciences</td>
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<td></td>
<td>- Understand and critically examine information from scientific journals and media</td>
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<td></td>
<td>- Understand pedagogically relevant findings from the empirical educational sciences</td>
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<tr>
<td>851-0242-11L</td>
<td>Gender Issues in Education and STEM ■ W</td>
<td>W</td>
<td>2</td>
<td>2S</td>
<td>M. Berkowitz Biran, T. Braas,</td>
</tr>
<tr>
<td></td>
<td>Number of participants limited to 30.</td>
<td></td>
<td></td>
<td></td>
<td>C. M. Thurn</td>
</tr>
<tr>
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<td>Enrolment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).</td>
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<td></td>
<td><strong>Prerequisite:</strong> students should be taking the course 851-0240-00L Human Learning (EW 1) in parallel, or to have successfully completed it.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>In this seminar, we introduce some of the major gender-related issues in the context of education and science learning, such as the under-representation of girls and women in science, technology, engineering and mathematics (STEM). Common perspectives, controversies and empirical evidence will be discussed.</td>
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<td></td>
<td><strong>Objective</strong></td>
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<tr>
<td></td>
<td>- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues</td>
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<td></td>
<td>- To develop a critical view on existing research and perspectives.</td>
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<td></td>
<td>- To integrate this knowledge with teacher's work.</td>
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<tr>
<td></td>
<td><strong>Content</strong></td>
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<tr>
<td></td>
<td>Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.</td>
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<td></td>
<td>The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.</td>
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<td></td>
<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td></td>
<td>Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).</td>
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</tbody>
</table>

**see Educational Science Teaching Diploma**

## Subject Didactics in Physics

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0910-00L</td>
<td>Physics Didactics I: Special Didactics of Physics Teaching ■ O</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>
Die Studierenden verfügen über fachdidaktisches Grundwissen für den Physikunterricht an einer Mittelschule. Sie können eigene Lektionen unter Berücksichtigung der vielfältigen Rahmenbedingungen planen, durchführen und evaluiern. Sie reflektieren ihren Unterricht und sind bestrebt, ihn didaktisch und pädagogisch weiter zu entwickeln.


**Objective**

- Die Studierenden verfügen über fachdidaktisches Grundwissen für den Physikunterricht an einer Mittelschule. Sie können eigene Lektionen unter Berücksichtigung der vielfältigen Rahmenbedingungen planen, durchführen und evaluieren. Sie reflektieren ihren Unterricht und sind bestrebt, ihn didaktisch und pädagogisch weiter zu entwickeln.
- Die Studierenden kennen die Einsatzmöglichkeiten, Chancen und Schwierigkeiten verschiedener Unterrichtsprozesse und Hilfsmittel. Sie können die Eignung von Unterrichtsformen im Hinblick auf eine Lernsituation beurteilen. Sie bemühen sich in ihrem Unterricht, geeignete Methoden und Medien angepasst an die Klasse und das Thema einzusetzen.

**Content**

- Thematische Schwerpunkte
  - Fachspezifisches: Sachstrukturen der gängigen Unterrichtsthemen, Alltagsbezüge, Fehlvorstellungen, Demonstrations- und Schülerexperimente, Arbeitsmittel zu physikalischen Themen des Grundlagen- und Schwerpunktunterrichts
  - Einsatz verschiedener Unterrichtsmaterialien: Experimente, Computer, Taschenrechner, Video, Simulation
  - Unterrichtsformen: Lernaufgabe, Werkstatt, Puzzle, Projekt, Gruppenarbeit, Praktikum
  - Lernformen
  - Interaktive Lehr-Lernveranstaltung mit Vorträgen und Demonstrationen des Dozenten, studentischer Einzel- und Kleingruppenarbeit, kurzen Präsentationen der Studierenden, Verleihung der Inhalte durch Bearbeitung von Aufträgen ausserhalb der Kontaktstunden

**Lecture notes**

- Folien und weitere Unterlagen werden zur Verfügung gestellt
- Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen

**Prerequisites / notice**

- Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen
- The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Domains**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies

- **Domain B - Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Problem-solving
  - Project Management

- **Domain C - Social Competencies**
  - Communication
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation

- **Domain D - Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

**Methods**

- With the help of the mentor the students individually work on a topic and write a thesis about it.
- The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

**Taught competencies**

- **Domain A**
  - Subject-specific Competencies
    - Concepts and Theories
    - Techniques and Technologies

- **Domain B**
  - Method-specific Competencies
    - Analytical Competencies
    - Decision-making
    - Problem-solving
    - Project Management

- **Domain C**
  - Social Competencies
    - Communication
    - Customer Orientation
    - Leadership and Responsibility
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    - Negotiation

- **Domain D**
  - Personal Competencies
    - Adaptability and Flexibility
    - Creative Thinking
    - Critical Thinking
    - Integrity and Work Ethics
    - Self-awareness and Self-reflection
    - Self-direction and Self-management

---

**Information for UZH students:**

- Enrolment to this course unit only possible at ETH. No enrolment to module 090Phy1 at UZH.

Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

**Objective**

- The objective is for the students:
  - to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
  - to show that they can independently compile a tuition sequence that is conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

**Content**

- Thematic Focus
  - The topics of the mentored work are mostly chosen from the high school curriculum.

**Lecture notes**

- Folien und weitere Unterlagen werden zur Verfügung gestellt
- Die Veranstaltung ist zusammen mit dem Einführungspraktikum zu belegen
Abstract
In their mentored work on subject didactics, students put into practice the contents of the subject-didactics lectures and go into these in greater depth. Under supervision, they compile tuition materials that are conducive to learning and/or analyse and reflect on certain topics from a subject-based and pedagogical angle.

Objective
The objective is for the students:
- to be able to familiarise themselves with a tuition topic by consulting different sources, acquiring materials and reflecting on the relevance of the topic and the access they have selected to this topic from a specialist, subject-didactics and pedagogical angle and potentially from a social angle too.
- to show that they can independently compile a tuition sequence that is conducive to learning and develop this to the point where it is ready for use.

Content
Focus of contents
The topics of the mentored work are mostly chosen from the high school curriculum.

Methods
With the help of the mentor the students individually work on a topic and write a thesis about it.

Lecture notes
http://www.fachdidaktik.physik.ethz.ch/unterlagen.html

Prerequisites / notice
The mentored work should usually be finished before the teaching internship. FD2 (402-0909-00L) is required or should be achieved in the same semester.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | assessed |
| | Problem-solving | assessed |
| | Project Management | assessed |
| Domain C - Social Competencies | Communication and Teamwork | assessed |
| | Customer Orientation | assessed |
| | Leadership and Responsibility | assessed |
| | Self-presentation and Social Influence | assessed |
| | Sensitivity to Diversity | assessed |
| | Negotiation | assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |
| | Self-direction and Self-management | assessed |

Professional Training in Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0920-00L</td>
<td>Introductory Internship Physics</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>M. Mohr</td>
</tr>
</tbody>
</table>

Simultaneous enrolment in Physics Didactics - Special Didactics of Physics Teaching - course 402-0910-00L - is compulsory.

Abstract
During the introductory teaching practice, the students sit in on five lessons given by the teacher responsible for their teaching practice, and teach five lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.

Objective
Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.

Content
Den Studierenden bietet das Einführungspraktikum einen Einblick in den Berufssalltag einer Lehrperson.

Literature
Wird von der Praktikumslehrperson bestimmt.

402-0911-00L | Teaching Internship Physics | O | 8 | 17P | M. Mohr |

Abstract
The teaching practice takes in 50 lessons: 30 are taught by the students, and the students sit in on 20 lessons. The teaching practice lasts 4-6 weeks. It gives students the opportunity to implement the contents of their specialist-subject, educational science and subject-didactics training in the classroom. Students also conduct work assignments in parallel to their teaching practice.

Objective
- Students use their specialist-subject, educational-science and subject-didactics training to draw up concepts for teaching.
- They are able to assess the significance of tuition topics in their subject from different angles (including interdisciplinary angles) and impart these to their pupils.
- They acquire the skills of the teaching trade.
- They practise finding the balance between instruction and openness so that pupils can and, indeed, must make their own cognitive contribution.
- They learn to assess pupils' work.
- Together with the teacher in charge of their teacher training, the students constantly evaluate their own performance.

Content

Literature
Wird von der Praktikumslehrperson bestimmt.
402-0913-00L  
Teaching Internship Physics II  
Teaching Internship for students upgrading TC to Teaching Diploma.

Abstract  
This is a supplement to the Teaching Internship required to obtain a Master of Advanced Studies in Secondary and Higher Education in the corresponding subject. It is aimed at enlarging the already acquired teaching experience. Students observe 10 lessons and teach 15 lessons independently.

Objective  
Die Studierenden können die Bedeutung von Unterrichtsthemen in ihrem Fach unter verschiedenen Blickwinkeln einschätzen. Sie kennen und beherrschen das unterrichtliche Handwerk. Sie können ein gegebenes Unterrichtsthema für eine Gruppe von Lernenden fachlich und didaktisch korrekt strukturieren und in eine adäquate Lernumgebung umsetzen. Es gelingt ihnen, die Balance zwischen Anleitungs- und Offenheit zu finden, sodass die Lernenden sowohl über den nötigen Freiraum wie über ausreichend Orientierung verfügen, um aktiv und effektiv flexibel nutzbares (Fach-)Wissen zu erwerben.

Content  

402-0921-01L  
Examination Lesson I Physics  
Simultaneous enrolment in “Examination Lesson II Physics” (402-0921-02L) is compulsory.

Abstract  
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective  
On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content  

Lecture notes  
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice  
Nach Abschluss der übrigen Ausbildung.

402-0921-02L  
Examination Lesson II Physics  
Simultaneous enrolment in “Examination Lesson I Physics” (402-0921-01L) is compulsory.

Abstract  
In the context of an examination lesson conducted and graded at a high school, the candidates provide evidence of the subject-matter-based and didactic skills they have acquired in the course of their training.

Objective  
On the basis of a specified topic, the candidate shows that they are in a position - to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle - to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Content  

Lecture notes  
Dokument: Schriftliche Vorbereitung für Prüfungslektionen.

Prerequisites / notice  
Nach Abschluss der übrigen Ausbildung.


Core courses that counted towards the Bachelor or Master programme in physics or comprised additional admission requirements in subject didactics are not eligible for the teaching diploma.
### Content


### Lecture notes

Web page:

http://ihp-lx2.ethz.ch/energy21/index.html

### Literature

- The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
- Clean Disruption of Energy and Transportation, T. Seba 2014
- Energy and Civilization: A History, V. Smil, 2018
- Renewable Energy – Without the Hot Air, D.J.C. Mackay 2009

### Prerequisites / notice

Basics of Physics applied to Energy and Energy Technology. Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions. Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

### 402-0922-00L

**Mentored Work Specialised Courses in Physics with an Educational Focus A**

<table>
<thead>
<tr>
<th>Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for TC and Teaching Diploma.</th>
<th>W</th>
<th>2 credits</th>
<th>4A</th>
<th>G. Schiltz, A. Vaterlaus</th>
</tr>
</thead>
</table>

**Abstract**

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

**Objective**

Practice in the explanation of complex topics in physics as the core competence of the teaching profession.

**Content**

Choice of topic by individual arrangement.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th>Analytical Competencies</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision-making</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain C - Social Competencies</th>
<th>Communication</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Negotiation</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain D - Personal Competencies</th>
<th>Adaptability and Flexibility</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
<td>assessed</td>
<td></td>
</tr>
</tbody>
</table>

### 402-0923-00L

**Mentored Work Specialised Courses in Physics with an Educational Focus B**

<table>
<thead>
<tr>
<th>Mentored Work Specialised Courses in the Respective Subject with an Educational Focus in Physics for Teaching Diploma and for students upgrading TC to Teaching Diploma.</th>
<th>W</th>
<th>2 credits</th>
<th>4A</th>
<th>G. Schiltz, A. Vaterlaus</th>
</tr>
</thead>
</table>

**Abstract**

In the mentored work on their subject specialisation, students link high-school and university aspects of the subject, thus strengthening their teaching competence with regard to curriculum decisions and the future development of the tuition. They compile texts under supervision that are directly comprehensible to the targeted readers - generally specialist-subject teachers at high-school level.

**Objective**

Practice in the explanation of complex topics in physics as the core competence of the teaching profession.

**Content**

Choice of topic by individual arrangement.
Physics in the Smartphone

Internship Physics Didactics for Teaching Diploma with Physics as First Subject.

402-0924-00L Internship Physics Didactics

- Taught competencies
  - Domain A - Subject-specific Competencies
    - Concepts and Theories
    - Techniques and Technologies
  - Domain B - Method-specific Competencies
    - Analytical Competencies
    - Decision-making
    - Problem-solving
    - Project Management
  - Domain C - Social Competencies
    - Communication
    - Cooperation and Teamwork
    - Customer Orientation
    - Leadership and Responsibility
    - Self-presentation and Social Influence
    - Sensitivity to Diversity
  - Domain D - Personal Competencies
    - Adaptability and Flexibility
    - Critical Thinking
    - Negotiation

- Objective
  Students develop, test and analyze teaching arrangement under the guidance of a mentor (one of the lecturers).

- Content
  - The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

- Literature
  - W. Känzig, Kondensierte Materie
  - Ashcroft & Mermin, Festkörperphysik
  - C. Kittel, Festkörperphysik

- Prerequisites / notice

- Lecture notes
  - Wird vom Mentor bestimmt.

402-0263-00L Astrophysics I

- Objective
  - The course provides an overview of fundamental concepts and physical processes in astrophysics with the dual goals of: i) illustrating physical principles through a variety of astrophysical applications; and ii) providing an overview of research topics in astrophysics.

- Literature
  - Ibach & Lüth, Festkörperphysik
  - C. Kittel, Festkörperphysik
  - Ashcroft & Mermin, Festkörperphysik
  - W. Känzig, Kondensierte Materie

- Prerequisites / notice
  - Das Fachdidaktikpraktikum kann erst nach dem Besuch der FD1 und frühestens mit der FD2 durchgeführt werden (eine gleichzeitige Belegung von Fachdidaktik 2 und Fachdidaktikpraktikum ist möglich).

402-0255-00L Introduction to Solid State Physics

- Objective
  - The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; interatomic bindings; lattice dynamics, electronic properties of insulators, metals, semiconductors, transport properties, magnetism, superconductivity.

- Literature
  - The script will be available on moodle.
  - Ibach & Lüth, Festkörperphysik
  - C. Kittel, Festkörperphysik
  - Ashcroft & Mermin, Festkörperphysik
  - W. Känzig, Kondensierte Materie

- Prerequisites / notice
  - Voraussetzungen: Physik I, II, III wünschenswert

402-0505-00L Physics in the Smartphone

- Objective
  - Students recognize and appreciate the enormous impact "physics" has on today's high tech world. Abstract concepts, old and recent, encountered in the lectures are implemented and present all around us.

- Content
  - We explore how traditional and new physics concepts and achievements make their way into today's ubiquitous high-tech gadget : the smartphone. Examples of topics include: network topology and scratch proof Gorilla glass, spin-orbit coupling makes for four times brighter displays, no GPS without general theory of relativity, electromagnetic response of matter (transparent metals for displays, GPS signal propagation in the atmosphere), lightfield cameras replacing CCD and CMOS light sensors, physical limitations to IC scaling: the end of "Moore's law", meta-materials for antennas, physics of the various MEMS sensors, etc., etc..

- Lecture notes
  - The presentation material and original literature will be distributed weekly.
### Prerequisites / notice

Basic physics lectures and introduction to solid state physics are expected.

This is a "3 hour" course, with two hours set for <tba>, and the third one to be set at the beginning of the semester.

An introductory event is planned in the first week of the term on Wednesday, September 19th - 17:45 in the room HIT KS1. In this meeting we will fix the time of the usual lecture and we will distribute the topics for the presentations during the term. The tutorials will Briefly present each topic.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0247-00L</td>
<td>Electronics for Physicists I (Analogue)</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2P</td>
<td>G. Bison, W. Erdmann</td>
</tr>
</tbody>
</table>

**Abstract**

Passive components, linear networks, transmission lines, simulation of analog circuits, semiconductor components: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise, operational amplifiers, feedback and stability, oscillators, ADCs and DACs, introduction to CMOS technology.

**Objective**

The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

**Content**

Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADC's and DAC's, introduction in CMOS technology. Practical exercises in small groups to the above themes complement the lectures.

**Prerequisites / notice**

No prior knowledge in electronics is required.

### Taught competencies

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
  - not assessed

- **Domain B - Method-specific Competencies**
  - Problem-solving
  - not assessed

- **Domain C - Social Competencies**
  - Cooperation and Teamwork
  - not assessed

- **Domain D - Personal Competencies**
  - Creative Thinking
  - Critical Thinking
  - not assessed

### Compulsory Elective Courses

Further course offerings from the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

**Objective**

- Why is energy important for life and our society?
- How did energy use change over time? Which effects did these changes have on the environment?
- What are the physical basics of energy technologies?
- When, why and how did technology and science of energy come together?
- What are the limits and benefits of all the various energy technologies?
- How can different energy technologies be compared?
- Can we understand the changes in the current energy systems?
- How will the energy systems of the future look like?
- How fast can we and should we alter the current energy transition?
- Which could be the overall guidelines for a working energy system of the future?

**Content**

- Physical basics of energy, thermodynamics and life. Introduction to self-organisation, and systems.
- Energy and making use of it - a short history and overview on energy technologies
- Coal, oil and natural gas – fossil fuels
- Hydro, Wind & Solarpower (Geothermal- and Tidal power) – the quest for renewable energy
- Nuclear power, radioactivity and ultimate storage – the quest for a safe technology
- Energy storage – available technologies and a technology outlook
- Climate change, decarbonisation – how much time do we have?
- Energy efficiency, recycling and other resource conservation measures
- Energy systems – how everything can play together
- Buildings and Mobility – new technologies, new Ways of life?
- Life cycle assessment of Energy Technologies – problems and possibilities
- Economics of energy, learning curves, technology assessments and Innovation.
- The energy transition and decarbonisation – How is your 2040, 2050?

**Lecture notes**


**Literature**

- [The Physics of Energy, R.L. Jaffe, W. Taylor, 2018](http://example.com)
- [Clean Disruption of Energy and Transportation, T. Seba 2014](http://example.com)
- [Clean Disruption of Energy and Transportation, T. Seba 2014](http://example.com)
- [Renewable Energy – Without the Hot Air, D.J.c. Mackay 2009](http://example.com)

**Prerequisites / notice**

- Basics of Physics applied to Energy and Energy Technology.
- Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions
- Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0855-00L</td>
<td>Computer Science in Secondary School Mathematics</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>J. Hromkovic, G. Serafini</td>
</tr>
</tbody>
</table>

**Abstract**

The unit "Computer Science in Secondary School Mathematics" addresses key contributions of computer science to general education, the tight relations between the algorithmic and the mathematical way of thinking, and the thoughtful choice of computer science topics for high school mathematics classes.
The general goal of the course consists in presenting ways to teach fundamentals of computer science, which are closely related to contents and methods of mathematics. After attending the course unit, a mathematics teacher is able to teach selected fundamentals of computer science in mathematics classes.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value.

The course covers the didactics of logic, of cryptography, of finite state automata, of computability and of the introduction to programming. The students develop the understanding of fundamental scientific concepts such as algorithm, program, complexity, determinism, computation, automata, verification, testing, security of a cryptosystem and secure communication. They reflect on ways to embed them into a scientifically sound and didactically sustainable mathematics course.

In a semester exercise, the students develop and document an adaptive teaching unit for computer science. They learn to employ the didactics methods and techniques that are introduced at the beginning of the semester.

The students understand the fundamental concepts of computer science in the context of a broad and deep knowledge. Through this understanding, they manage to prepare teaching materials for a successful knowledge transfer and to pass their passion for the subject on to their pupils.

The students know various teaching methods as well as their advantages and disadvantages. They can handle inhomogeneous prior knowledge of the learners inside a class. Besides holding classes, the students do care about the individual pupil support.

They encourage the autonomy of the learners, manage to work with diverse target groups and to establish a positive learning environment.

The students are able to express themselves using a comprehensible and refined professional language, both in a spoken and a written way, and they master the basic terminology of computer science. Besides the English terms, they are familiar with the corresponding German expressions. The students are able to produce detailed, matured, linguistically correct and design-wise appealing teaching materials.

The main topics of the course unit "Computer Science in Secondary School Mathematics" represent a scientific and didactic added value.
# Physics Master

**Core Courses**

One Core Course in Experimental or Theoretical Physics from Physics Bachelor is eligible; however, this Core Course from Physics Bachelor cannot be used to compensate for the mandatory Core Course in Experimental or Theoretical Physics.

For the category assignment keep the choice "no category" and take contact with the Study Administration ([www.phys.ethz.ch/studies/study-administration.html](http://www.phys.ethz.ch/studies/study-administration.html)) after having received the credits.

**Core Courses in Theoretical Physics**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0861-00L</td>
<td>Statistical Physics</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>M. Sigrist</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This lecture covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.</td>
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<td>Objective</td>
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<td></td>
<td>This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics education.</td>
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<tr>
<td></td>
<td>Content</td>
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<tr>
<td></td>
<td>Lecture notes</td>
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<tr>
<td></td>
<td>Lecture notes available in English.</td>
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<tr>
<td></td>
<td>Literature</td>
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<tr>
<td></td>
<td>No specific book is used for the course. Relevant literature will be given in the course.</td>
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<tr>
<td>402-0843-00L</td>
<td>Quantum Field Theory I</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>G. M. Graf</td>
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<td><em>Special Students UZH must book the module PHY51 directly at UZH.</em></td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>This course discusses the quantisation of fields in order to introduce a coherent formalism for the combination of quantum mechanics and special relativity. Topics include: Relativistic quantum mechanics - Quantisation of bosonic and fermionic fields - Interactions in perturbation theory - Scattering processes and decays - Elementary processes in QED - Radiative corrections</td>
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<td>Objective</td>
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<td>The goal of this course is to provide a solid introduction to the formalism, the techniques, and important physical applications of quantum field theory. Furthermore it prepares students for the advanced course in quantum field theory (Quantum Field Theory II), and for work on research projects in theoretical physics, particle physics, and condensed-matter physics.</td>
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<td>Lecture notes</td>
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<td>Will be provided as the course progresses</td>
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<td>Taught competencies</td>
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<td>Domain A - Subject-specific Competencies</td>
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<td>Concepts and Theories</td>
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<td>Techniques and Technologies</td>
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<td>Domain B - Method-specific Competencies</td>
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<td></td>
<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Domain C - Social Competencies</td>
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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td>Self-direction and Self-management</td>
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Core Courses: Experimental Physics

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>402-0257-00L</td>
<td>Advanced Solid State Physics</td>
<td>W</td>
<td>10 credits</td>
<td>3V+2U</td>
<td>K. Povarov</td>
</tr>
</tbody>
</table>

Abstract
This course is an extension of the introductory course on solid state physics.

The purpose of this course is to learn to navigate the complex collective quantum phases, excitations and phase transitions that are the dominant theme in modern solid state physics. The emphasis is on the main concepts and on specific experimental examples, both classic ones and those from recent research.

Objective
The goal is to study how novel phenomena emerge in the solid state.

Content
- Phase transitions and critical phenomena
  - Main concepts: coherence length, symmetry, order parameter, correlation functions, generalized susceptibility
  - Bragg-Williams mean field theory
  - Landau theory of phase transitions
  - Fluctuations in Landau theory
  - Critical exponents: significance, measurement, inequalities, equalities
  - Scaling and hyperscaling
  - Universality
  - Critical dynamics
  - Quantum phase transitions and quantum criticality
- Fermi surface instabilities
  - The concept of the Landau Fermi liquid in metals
  - Kohn anomalies
  - Charge density waves
  - Metallic ferromagnets and half-metals
  - Spin density waves
- Magnetism of insulators
  - Magnetic interactions in solids and the spin Hamiltonian
  - Magnetic structures and phase transitions
  - Spin waves
  - Quantum magnetism
- Electron correlations in solids
  - Mott insulating state
  - Phases of the Hubbard model
  - Layered cuprates (non-superconducting properties)

Lecture notes
The printed material for this course involves: (1) a self-contained script, distributed electronically at semester start. (2) experimental examples (Power Point slide-style) selected from original publications, distributed at the start of every lecture.

Literature
A list of books will be distributed. Numerous references to useful published scientific papers will be provided.

Prerequisites / notice
This course is for students who like to be engaged in active learning. The "exercise classes" are organized in a non-traditional way: following the idea of "less is more", we will work on only about half a dozen topics, and this gives students a chance to take a look at original literature (provided), and to get the grasp of a topic from a broader perspective.

Students report back that this mode of "exercise class" is more satisfying than traditional modes, even if it does not mean less effort.

402-0442-00L Quantum Optics W 10 credits 3V+2U T. Esslinger

Abstract
This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics and quantum computation.

Objective
The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.

Content
This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:
- coherence properties of light
- quantum nature of light: statistics and non-classical states of light
- light matter interaction: density matrix formalism and Bloch equations
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,
- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

Lecture notes
Selected book chapters will be distributed.

Literature
Text-books:
- G. Grynegb, A. Aspect and C. Fabre, Introduction to Quantum Optics
- R. Loudon, The Quantum Theory of Light
- Atomic Physics, Christopher J. Foot
- Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guery-Odelin
- C. Cohen-Tannoudji et al., Atom-Photon-Interactions
- M. Scully and M.S. Zubairy, Quantum Optics
- Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

402-0402-00L Ultrafast Laser Physics W 10 credits 3V+2U L. P. Gallmann, S. Johnson, U. Keller

Abstract
Introduction to ultrafast laser physics with an outlook into cutting edge research topics such as attosecond science and coherent ultrafast sources from THz to X-rays.
Objective
Understanding of basic physics and technology for pursuing research in ultrafast laser science. How are ultrashort laser pulses generated, how do they interact with matter, how can we measure these shortest man-made events and how can we use them to time-resolve ultrafast processes in nature? Fundamental concepts and techniques will be linked to a selection of hot topics in current research and applications.

Content
The lecture covers the following topics:

a) Linear pulse propagation: mathematical description of pulses and their propagation in linear optical systems, effect of dispersion on ultrashort pulses, concepts of pulse carrier and envelope, time-bandwidth product

b) Dispersion compensation: technologies for controlling dispersion, pulse shaping, measurement of dispersion

c) Nonlinear pulse propagation: intensity-dependent refractive index (Kerr effect), self-phase modulation, nonlinear pulse compression, self-focusing, filamentation, nonlinear Schrödinger equation, solitons, non-instantaneous nonlinear effects (Raman/Brillouin), self-steepening, saturable gain and absorption

d) Second-order nonlinearities with ultrashort pulses: phase-matching with short pulses and real beams, quasi-phase matching, second-harmonic and sum-frequency generation, parametric amplification and generation

e) Relaxation oscillations: dynamical behavior of rate equations after perturbation

f) Q-switching: active Q-switching and its theory based on rate equations, active Q-switching technologies, passive Q-switching and theory

g) Active modelocking: introduction to modelocking, frequency comb versus axial modes, theory for various regimes of laser operation, Haus master equation formalism

h) Passive modelocking: slow, fast and ideally fast saturable absorbers, semiconductor saturable absorber mirror (SESAM), designs of and materials for SESAMs, modelocking with slow absorber and dynamic gain saturation, modelocking with ideally fast saturable absorber, Kerr-lens modelocking, soliton modelocking, Q-switching instabilities in modelocked lasers, inverse saturable absorption

i) Pulse duration measurements: rf cables and electronics, fast photodiodes, linear system theory for microwave test systems, intensity and interferometric autocorrelations and their limitations, frequency-resolved optical gating, spectral phase interferometry for direct electric-field reconstruction and more

j) Noise: microwave spectrum analyzer as laser diagnostics, amplitude noise and timing jitter of ultrafast lasers, lock-in detection

k) Ultrafast measurements: pump-probe scheme, transient absorption/differential transmission spectroscopy, four-wave mixing, optical gating and more

l) Frequency combs and carrier-envelope offset phase: measurement and stabilization of carrier-envelope offset phase (CEP), time and frequency domain applications of CEP-stabilized sources

m) High-harmonic generation and attosecond science: non-perturbative nonlinear optics / strong-field phenomena, high-harmonic generation (HHG), phase-matching in HHG, attosecond pulse generation, attosecond technology: detectors and diagnostics, attosecond metrology (streaking, RABBITT, transient absorption, attoclock), example experiments

n) Ultrafast THz science: generation and detection, physics in THz domain, weak-field and strong-field applications

o) Brief introduction to other hot topics: relativistic and ultra-high intensity ultrafast science, ultrafast electron sources, free-electron lasers, etc.

Lecture notes
Class notes will be made available.

Prerequisites / notice
Prerequisites: Basic knowledge of quantum electronics (e.g., 402-0275-00L Quantenelektronik).

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

402-0891-00L Phenomenology of Particle Physics I
W 10 credits 3V+2U P. Crivelli, A. de Cosa

Abstract
Topics to be covered in Phenomenology of Particle Physics I: Relativistic kinematics Decay rates and cross sections The Dirac equation From the S-matrix to the Feynman rules of QED Scattering processes in QED Experimental tests of QED Hadron spectroscopy Unitary symmetries and QCD QCD and alpha_s running QCD in e^+e^- annihilation Experimental tests of QCD in e^+e^- annihilation

Objective
Introduction to modern particle physics

Content
Topics to be covered in Phenomenology of Particle Physics I: Relativistic kinematics Decay rates and cross sections The Dirac equation From the S-matrix to the Feynman rules of QED Scattering processes in QED Experimental tests of QED Hadron spectroscopy Unitary symmetries and QCD QCD and alpha_s running QCD in e^+e^- annihilation Experimental tests of QCD in e^+e^- annihilation

Literature
As described in the entity: Lernmaterialien

Electives
Electives: Physics and Mathematics
Selection: Solid State Physics
<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tr>
<td>402-0525-00L</td>
<td>Ultrafast Processes in Solids</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>Y. M. Acremann</td>
</tr>
</tbody>
</table>

**Abstract**

Ultrafast processes in solids are of fundamental interest as well as relevant for modern technological applications. The dynamics of the lattice, the electron gas as well as the spin system of a solid are discussed. The focus is on time resolved experiments which provide insight into pico- and femtosecond dynamics.

**Objective**

After attending this course you understand the dynamics of essential excitation processes which occur in solids and you have an overview over state of the art experimental techniques used to study fast processes.

**Content**

1. Experimental techniques, an overview
   1.1 First experiments on electron dynamics and lattice heating
   1.2 The finite lifetime of excited states
   1.3 Detection of lifetime effects
   1.4 Dynamical properties of reactions and adsorbents
2. Dynamics of the lattice
   2.1 Phonons
   2.2 Non-thermal melting
3. Dynamics of the electron gas
   3.1 Fermions
   3.2 Laser induced ultrafast demagnetization
   3.3 Ultrafast spin currents generated by lasers
   3.4 Landau-Lifschitz-Dynamics
   3.5 Laser induced switching
4. Dynamics of the spin system
   4.1 Conductance quantization in quantum point contacts
   4.2 Interference effects in Aharonov-Bohm rings

**Literature**

- Relevant publications will be cited

**Prerequisites / notice**

The lecture can also be followed by interested non-physics students as basic concepts will be introduced.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
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<tr>
<td>402-0535-00L</td>
<td>Introduction to Magnetism</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>A. Vindigni</td>
</tr>
</tbody>
</table>

**Abstract**

Atomic paramagnetism and diamagnetism, itinerant and local-moment interatomic coupling, magnetic order at finite temperature, spin precession, approach to equilibrium through thermal and quantum dynamics, dipolar interaction in solids.

**Objective**

- Apply concepts of quantum-mechanics to estimate the strength of atomic magnetic moments and their interactions
- Identify the mechanisms from which exchange interaction originates in solids (itinierant and local-moment magnetism)
- Evaluate the consequences of the interplay between competing interactions and thermal energy
- Apply general concepts of statistical physics to determine the origin of bistability in realistic magnets
- Discriminate the dynamic responses of a magnet to different external stimuli

**Content**

The lecture "Introduction to Magnetism" is a regular course of the Physics MSc program and aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what "being magnetic" means is essential to address this question properly. Theoretical concepts will be applied to few selected nano-sized magnets, which will serve as clean reference systems.

At the end of this course students should have acquired the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Preliminary contents for the HS21:

- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field).
- Spin resonance and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)
- Magnetic order at finite temperatures (Ising and Heisenberg models, low-dimensional magnetism)
- Dipolar interaction in solids (shape anisotropy, dipolar frustration, origin of magnetic domains)

**Lecture notes**

Learning material will be made available through a dedicated RStudioServer and through Moodle.

**Prerequisites / notice**

Students are assumed to possess a basic background knowledge in quantum mechanics, solid-state and statistical physics as well as classical electromagnetism. Students will have the opportunity to self-assess their understanding through quizzes and interactive tutorials, mostly inspired by topics of current research in nanoscale magnetism.

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<tr>
<td>402-0595-00L</td>
<td>Semiconductor Nanostructures</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>T. M. Ihn</td>
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</table>

**Abstract**

The course covers the foundations of semiconductor nanostructures, e.g., materials, band structures, bandgap engineering and doping, field-effect transistors. The physics of the quantum Hall effect and of common nanostructures based on two-dimensional electron gases will be discussed, i.e., quantum point contacts, Aharonov-Bohm rings and quantum dots.

**Objective**

At the end of the lecture the student should understand four key phenomena of electron transport in semiconductor nanostructures:

1. The integer quantum Hall effect
2. Conductance quantization in quantum point contacts
3. the Aharonov-Bohm effect
4. Coulomb blockade in quantum dots

**Content**

1. Introduction and overview
2. Semiconductor crystals: Fabrication and molecular beam epitaxy
3. Band structures of semiconductors
4. k-p-theory, effective mass, envelope functions
5. Heterostructures and band engineering, doping
6. Surfaces and metal-semiconductor contacts, fabrication of semiconductor nanostructures
7. Heterostructures and two-dimensional electron gases
8. Drude Transport and scattering mechanisms
9. Single- and bilayer graphene
10. Electron transport in quantum point contacts; Landauer-Büttiker description, ballistic transport experiments
11. Interference effects in Aharonov-Bohm rings
12. Electron in a magnetic field, Shubnikov-de Haas effect
13. Integer quantum Hall effect
14. Coulomb blockade and quantum dots

**Lecture notes**

In addition to the lecture notes, the following supplementary books can be recommended:


### Prerequisites / notice

The lecture is suitable for all physics students beyond the bachelor of science degree. Basic knowledge of solid state physics is a prerequisite. Very ambitious students in the third year may be able to follow. The lecture can be chosen as part of the PhD-program. The course is taught in English.

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
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<td>Media and Digital Technologies</td>
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<td>Problem-solving</td>
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<td>Domain D - Personal Competencies</td>
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<td>Sensitivity to Diversity</td>
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</table>

### Literature


### Prerequisites / notice

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### Taught competencies

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<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

### Content

1. Fundamentals of Solid State Physics
2. Band structures
3. Carrier statistics in intrinsic and doped semiconductors
4. p-n junctions
5. Low-dimensional structures
6. Bulk Material growth of Semiconductors
7. Czochalski method
8. Floating zone method
9. High pressure synthesis
10. Semiconductor Epitaxy
11. Fundamentals of Epitaxy
12. Molecular Beam Epitaxy (MBE)
13. Metal-Organic Chemical Vapor Deposition (MOCDV)
14. Liquid Phase Epitaxy (LPE)
15. In Situ characterization
16. Pressure and temperature
17. Reflectometry
18. Ellipsometry and RAS
19. LEED, AES, XPS
20. STM, AFM
21. The invention of the transistor - Christmas lecture
22. Students will get a thorough introduction to the underlying physical concepts, the experimental setting, and the state-of-the-art of quantum computing in this emerging research field.

### Objective

Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing.

### Abstract

This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

### Literature


### Prerequisites / notice

The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture.

### Abstract

Superconducting Circuits provide a versatile experimental platform to explore the most intriguing quantum-physical phenomena and constitute one of the prime contenders to build quantum computers. Students will get a thorough introduction to the underlying physical concepts, the experimental setting, and the state-of-the-art of quantum computing in this emerging research field.

### Objective

Based on today's most advanced solid state platform for quantum control, the students will learn how to engineer quantum coherent devices and how to use them to process quantum information. The students will acquire both analytical and numerical methods to model the properties and phenomena observed in these systems. The course is positioned at the intersection between quantum physics and engineering.

### Content


### Prerequisites / notice

All students and researchers with a general interest in quantum information science, quantum optics, and quantum engineering are welcome to this course. Basic knowledge of quantum physics is a plus, but not a strict requirement for the successful participation in this course.

### Abstract

Physics in today's high-tech smartphone. Examples: network topology and scratch proof glass, spin-orbit coupling - brighter displays, GPS and general theory of relativity, electromagnetic response of matter (transparent metals for displays, GPS signal propagation), light-field cameras, CCD and CMOS light sensors, physics stops Moore's law, meta-materials for antennas, MEMS sensor physics, etc.

### Objective

Students recognize and appreciate the enormous impact "physics" has on today's high tech world. Abstract concepts, old and recent, encountered in the lectures are implemented and present all around us.

Students are actively involved in the preparation and presentation of the topics, and thus acquire valuable professional skills.
We explore how traditional and new physics concepts and achievements make their way into today's ubiquitous high-tech gadget: the smartphone. Examples of topics include:

- network topology and scratch proof Gorilla glass,
- spin-orbit coupling makes for four times brighter displays,
- no GPS without general theory of relativity,
- electromagnetic response of matter (transparent metals for displays, GPS signal propagation in the atmosphere),
- lightfield cameras replacing CCD and CMOS light sensors,
- physical limitations to IC scaling: the end of "Moore's law",
- meta-materials for antennas,
- physics of the various MEMS sensors,
- etc., etc.,

Lecture notes

The presentation material and original literature will be distributed weekly.

Prerequisites / notice

Basic physics lectures and introduction to solid state physics are expected.

This is a "3 hour" course, with two hours set for <tba>, and the third one to be set at the beginning of the semester.

An introductory event is planned in the first week of the term on Wednesday, September 19th - 17:45 in the room HIT K51. In this meeting we will fix the time of the usual lecture and we will distribute the topics for the presentations during the term. The tutors will briefly present each topics.

### Selection: Quantum Electronics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0464-00L</td>
<td>Optical Properties of Semiconductors</td>
<td>W</td>
<td>8 credits</td>
<td>2V+2U</td>
<td>J. Faist, P. Anantha Murthy</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course presents a comprehensive discussion of optical processes in semiconductors.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these material, enabled numerous applications (lasers, LEDs and solar cells) as well as the realization of new physical concepts. Systems that will be covered include quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Electronic states in III-V materials and quantum structures, optical transitions, excitons and polaritons, novel two dimensional semiconductors, spin-orbit interaction and magneto-optics.</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Prerequisites: Quantum Mechanics I, Introduction to Solid State Physics</td>
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<tr>
<td>402-0484-00L</td>
<td>Experimental and Theoretical Aspects of Quantum Gases</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>T. Esslinger</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>Quantum Gases are the most precisely controlled many-body systems in physics. This provides a unique interface between theory and experiment, which allows addressing fundamental concepts and long-standing questions. This course lays the foundation for the understanding of current research in this vibrant field.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The lecture conveys a basic understanding for the current research on quantum gases. Emphasis will be put on the connection between theory and experimental observation. It will enable students to read and understand publications in this field.</td>
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<tr>
<td><strong>Content</strong></td>
<td>Cooling and trapping of neutral atoms Bose and Fermi gases Ultracold collisions The Bose-condensed state Elementary excitations Vortices Superfluidity Interference and Correlations Optical lattices</td>
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<td><strong>Lecture notes</strong></td>
<td>notes and material accompanying the lecture will be provided</td>
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<tr>
<td>402-0444-00L</td>
<td>Advanced Quantum Optics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>A. Imamoglu</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
<td>This course builds up on the material covered in the Quantum Optics course. The emphasis will be on quantum optics in condensed-matter systems.</td>
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<td><strong>Objective</strong></td>
<td>The course aims to provide the knowledge necessary for pursuing advanced research in the field of Quantum Optics in condensed matter systems. Fundamental concepts and techniques of Quantum Optics will be linked to experimental research in systems such as quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Lecture notes will be provided</td>
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<tr>
<td><strong>Literature</strong></td>
<td>C. Cohen-Tannoudji et al., Atom-Photon-Interactions (recommended) Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics (recommended) A collection of review articles (will be pointed out during the lecture)</td>
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<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>Masters level quantum optics knowledge</td>
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<tr>
<td>402-0465-58L</td>
<td>Intersubband Optoelectronics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>G. Scalari</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Does not take place this semester.</td>
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<td><strong>Objective</strong></td>
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<tr>
<td><strong>Content</strong></td>
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<tr>
<td><strong>Lecture notes</strong></td>
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<tr>
<td><strong>Literature</strong></td>
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<td><strong>Prerequisites / notice</strong></td>
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</table>

Abstract
Intersubband transitions in quantum wells are transitions between states created by quantum confinement in ultra-thin layers of semiconductors. Because of its inherent taylorability, this system can be seen as the "ultimate quantum designer's material".

Objective
The goal of this lecture is to explore both the rich physics as well as the application of these system for sources and detectors. In fact, devices based on intersubband transitions are now unlocking large area of the electromagnetic spectrum.

Content
The lecture will treat the following chapters:
- Introduction: intersubband optoelectronics as an example of quantum engineering
- Technological aspects
- Electronic states in semiconductor quantum wells
- Intersubband absorption and scattering processes
- Mid-IR and THz ISB Detectors
- Mid-infrared and THz photonics: waveguides, resonators, metamaterials
- Quantum Cascade lasers:
  - Mid-IR QCLs
  - THZ QCLs (direct and non-linear generation)
- further electronic confinement: interlevel Qdot transitions and magnetic field effects
- Strong light-matter coupling in Mid-IR and THz range

Lecture notes
The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist , published by Oxford University Press.

Literature
Mostly the original articles, other useful reading can be found in:
- E. Rosencher and B. Vinter, Optoelectronics , Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

Prerequisites / notice
Requirements: A basic knowledge of solid-state physics and of quantum electronics.

Selection: Particle Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0715-00L</td>
<td>Low Energy Particle Physics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>A. Soter, P. A. Schmidt-Wellenburg</td>
</tr>
</tbody>
</table>

Abstract
Low energy particle physics provides complementary information to high energy physics with colliders. In this lecture, we will concentrate on flagship experiments which have significantly improved our understanding of particle physics today, concentrating mainly on precision experiments with neutrons, muons and exotic atoms.

Objective
You will be able to present and discuss:
- the principle of the experiments
- the underlying technique and methods
- the context and the impact of these experiments on particle physics

Content
Low energy particle physics provides complementary information to high energy physics with colliders. At the Large Hadron Collider one directly searches for new particles at energies up to the TeV range. In a complementary way, low energy particle physics indirectly probes the existence of such particles and provides constraints for "new physics", making use of high precision and high intensities.

Besides the sensitivity to effects related with new physics (e.g. lepton flavor violation, symmetry violations, CPT tests, search for electric dipole moments, new low mass exchange bosons etc.), low energy physics provides the best test of QED (electron g-2), the best tests of bound-state QED (atomic physics and exotic atoms), precise determinations of fundamental constants, information about the CKM matrix, precise information on the weak and strong force even in the non-perturbative regime etc.

Starting from a general introduction on high intensity/high precision particle physics and the main characteristics of muons and neutrons and their production, we will then focus on the discussion of fundamental problems and ground-breaking experiments:

- search for rare decays and charged lepton flavor violation
- electric dipole moments and CP violation
- spectroscopy of exotic atoms and symmetries of the standard model
- what atomic physics can do for particle physics and vice versa
- neutron decay and primordial nucleosynthesis
- atomic clock
- Penning traps
- Ramsey spectroscopy
- Spin manipulation
- neutron-matter interaction
- ultra-cold neutron production
- various techniques: detectors, cryogenics, particle beams, laser cooling....

Literature
Golub, Richardson & Lamoreaux: "Ultra-Cold Neutrons"
Rauch & Werner: "Neutron Interferometry"
Carlile & Willis: "Experimental Neutron Scattering"
Byrne: "Neutrons, Nuclei and Matter"  
Klapdor-Kleingrothaus: "Non Accelerator Particle Physics"

Prerequisites / notice
Einführung in die Kern- und Teilchenphysik / Introduction to Nuclear- and Particle-Physics

402-0767-00L Neutrino Physics W 6 credits 2V+1U A. Rubbia, D. Sgalaberna

Abstract
Theoretical basis and selected experiments to determine the properties of neutrinos and their interactions (mass, spin, helicity, chirality, oscillations, interactions with leptons and quarks).

Objective
Introduction to the physics of neutrinos with special consideration of phenomena connected with neutrino masses.

Lecture notes

Literature
D.O. Caldwell, Current Aspects of Neutrino Physics, Springer.

402-0725-00L Experimental Methods and Instruments of Particle Physics W 6 credits 3V+1U U. Langenegger, T. Schietinger, University lecturers

Special Students UZH must book the module PHY461 directly at UZH.
Abstract

Physics and design of particle accelerators.
Basics and concepts of particle detectors.
Track- and vertex-detectors, calorimetry, particle identification.
Special applications like Cherenkov detectors, air showers, direct detection of dark matter.
Simulation methods, readout electronics, trigger and data acquisition.
Examples of key experiments.

Objective

Acquire an in-depth understanding and overview of the essential elements of experimental methods in particle physics, including accelerators and experiments.

Content

1. Examples of modern experiments
2. Basics: Bethe-Bloch, radiation length, nucl. interaction length, fixed-target vs. collider, principles of measurements: energy- and momentum-conservation, etc
3. Physics and layout of accelerators
4. Charged particle tracking and vertexing
5. Calorimetry
6. Particle identification
7. Analysis methods: invariant and missing mass, jet algorithms, b-tagging
8. Special detectors: extended airshower detectors and cryogenic detectors
9. MC simulations (GEANT), trigger, readout, electronics

Lecture notes

Slides are handed out regularly, see http://www.physik.uzh.ch/en/teaching/PHY461/

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

402-0777-00L

Particle Accelerator Physics and Modeling I

W 6 credits 2V+1U A. Adelmann

Abstract

This is the first of two courses, introducing particle accelerators from a theoretical point of view and covers state-of-the-art modelling techniques.

Objective

You understand the building blocks of particle accelerators. Modern analysis tools allows you to model state-of-the-art particle accelerators. In some of the exercises you will be confronted with next generation machines. We will develop a Python (or Julia) simulation tool (pyAccLEGOrator or jAccLEGOrator) that reflects the theory from the lecture.

Content

Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

Literature

- R. K. Ellis, W. J. Stirling, B. R. Webber : "QCD and Collider Physics" (Cambridge Monographs on Particle Physics, Nuclear Physics & Cosmology)

Prerequisites / notice

Physics, Computational Science (RW) at BSc. Level

This lecture is also suited for PhD. students.

402-0851-00L

QCD: Theory and Experiment

W 3 credits 3G G. Dissertori, University lecturers

Abstract

An introduction to the theoretical aspects and experimental tests of QCD, with emphasis on perturbative QCD and related experiments at colliders.

Objective

Knowledge acquired on basics of perturbative QCD, both of theoretical and experimental nature. Ability to perform simple calculations of perturbative QCD, as well as to understand modern publications on theoretical and experimental aspects of perturbative QCD.

Content

QCD Lagrangian and Feynman Rules
QCD running coupling
Parton model
DGLAP
Basic processes
Experimental tests at lepton and hadron colliders
Measurements of the strong coupling constant

Literature

2) R. K. Ellis, W. J. Stirling, B. R. Webber : "QCD and Collider Physics" (Cambridge Monographs on Particle Physics, Nuclear Physics & Cosmology)

Prerequisites / notice

Will be given as block course, language: English.
For students of both ETH and University of Zurich.

Selection: Theoretical Physics

Number Title Type ECTS Hours Lecturers

402-0461-00L Quantum Information Theory W 8 credits 3V+1U P. Kammerlander

Abstract

The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

Objective

By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

Content

Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basics tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties. Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

Lecture notes

Distributed via moodle.

Literature

Nielsen and Chuang, Quantum Information and Computation
Preskill, Lecture Notes on Quantum Computation
Wilde, Quantum Information Theory
Watrous, The Theory of Quantum Information

402-0811-00L Programming Techniques for Scientific Simulations I W 5 credits 4G R. Käppeli
This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputer, optimization methods for scientific simulation codes are explained.

The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.

**402-0809-0OL**
Introduction to Computational Physics  
W 8 credits 2V+2U  
A. Adelmann

*Abstract*
This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and supercomputers. The course includes classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

*Objective*
Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

*Content*
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

*Lecture notes and slides* available online and will be distributed if desired.

*Literature recommendations* and references are included in the lecture notes.

*Prerequisites / notice*
Lecture notes and slides are available online and will be distributed if desired.

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**402-0580-0OL**
Superconductivity  
W 6 credits 2V+1U  
V. Geshkenbein

*Abstract*
Superconductivity: thermodynamics, London and Pippard theory; Ginzburg-Landau theory: spontaneous symmetry breaking, flux quantization, type I and II superconductors; microscopic BCS theory; electron-phonon mechanism, Cooper pairing, quasiparticle spectrum, thermodynamics and response to magnetic fields. Josephson effect: superconducting quantum interference devices (SQUID) and other applications.

*Objective*
Introduction to the most important concepts of superconductivity both on phenomenological and microscopic level, including experimental and theoretical aspects.

*Content*
This lecture course provides an introduction to superconductivity, covering both experimental as well as theoretical aspects. The following topics are covered:
- Basic phenomena of superconductivity: thermodynamics, electrodynamics, London and Pippard theory; Ginzburg-Landau theory: spontaneous symmetry breaking, flux quantization, properties of type I and II superconductors; mixed phase; microscopic BCS theory: electron-phonon mechanism, Cooper pairing, coherent state, quasiparticle spectrum, thermodynamics and response to magnetic fields; Josephson effects, superconducting quantum interference devices (SQUID) and other applications.

*Lecture notes*
Lecture notes and additional materials are available.

*Literature*
M. Tinkham "Introduction to Superconductivity"  
P. G. de Gennes "Superconductivity Of Metals And Alloys"  
A. A. Abrikosov "Fundamentals of the Theory of Metals"  
V. V. Schmidt "The Physics of Superconductors"

*Prerequisites / notice*
The preceeding attendance of the scheduled lecture courses "Introduction to Solid State Physics" and "Quantum Mechanics II" are mandatory. The lectures "Quantum Mechanics III" and "Solid State Theory" provide the most optimal conditions to follow this course.

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**402-0484-00L**
Experimental and Theoretical Aspects of Quantum Gases  
W 6 credits 2V+1U  
T. Esslinger

*Abstract*
Quantum Gases are the most precisely controlled many-body systems in physics. This provides a unique interface between theory and experiment, which allows addressing fundamental concepts and long-standing questions. This course lays the foundation for the understanding of current research in this vibrant field.

*Objective*
The lecture conveys a basic understanding for the current research on quantum gases. Emphasis will be put on the connection between theory and experimental observation. It will enable students to read and understand publications in this field.

*Content*
Cooling and trapping of neutral atoms  
- Bose and Fermi gases  
- Ultracold collisions  
- The Bose-condensed state  
- Elementary excitations  
- Vortices  
- Superfluidity  
- Interference and Correlations  
- Optical lattices

*Lecture notes*
Notes and material accompanying the lecture will be provided.

*Literature*

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**402-0833-0OL**
Particle Physics in the Early Universe  
W 6 credits 2V+1U

*Abstract*
An introduction to key concepts on the interface of Particle Physics and Early Universe cosmology. Topics include inflation and inflationary models, the Electroweak phase transition and vacuum stability, matter-antimatter asymmetry, recombination and the Cosmic Microwave Background, relic abundances and primordial nucleosynthesis, baryogenesis, dark matter and more.

*Objective*
The objectives of this course is to understand the evolution of the Universe at its early stages, as described by the Standard Model of cosmology, and delve into the insights and constraints imposed by cosmological observations on possible new particles beyond those discovered at the LHC.

*Prerequisites / notice*
Prerequisites: Particle Physics Phenomenology 1 or Quantum Field Theory 1  
Recommended: Quantum Field Theory 2, Advanced Field Theory, General Relativity
### 402-0897-00L Introduction to String Theory

<table>
<thead>
<tr>
<th><strong>W</strong></th>
<th>6 credits</th>
<th><strong>2V+1U</strong></th>
<th>J. Brödel</th>
</tr>
</thead>
</table>

**Abstract**
String theory is an attempt to quantise gravity and unite it with the other fundamental forces of nature. It is related to numerous interesting topics and questions in quantum field theory. In this course, an introduction to the basics of string theory is provided.

**Objective**
Within this course, a basic understanding and overview of the concepts and notions employed in string theory shall be given. More advanced topics will be touched upon towards the end of the course briefly in order to foster further research.

**Content**
- mechanics of point particles and extended objects
- string modes and their quantisation; higher dimensions, supersymmetry
- D-branes, T-duality
- supergravity as a low-energy effective theory, strings on curved backgrounds
- two-dimensional field theories (classical/quantum, conformal/non-conformal)

**Literature**
M. B. Green, J. H. Schwarz, E. Witten, Superstring Theory I, CUP (1987).

**Prerequisites / notice**
Recommended: Quantum Field Theory I (in parallel)

### 402-0469-67L Parametric Phenomena

<table>
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<tr>
<th><strong>W</strong></th>
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<th><strong>3G</strong></th>
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**Abstract**
There are numerous physical phenomena that rely on time-dependent Hamiltonians (or parametric driving) to amplify, cool, squeeze or couple resonating systems. In this course, we shall introduce parametric phenomena in different fields of physics, ranging from classical engineering ideas to devices proposed for quantum neural networks.

**Objective**
In this course, the students will grasp the ubiquitous nature of parametric phenomena and apply it to both classical and quantum systems. The students will understand both the theoretical foundations leading to the parametric drive as well as the experimental aspect related to the realizations of the effect. Each student will analyze an independent system using the tools acquired in the course and will present his/her insights to the class.

**Content**
This course will provide a general framework for understanding and linking various phenomena, ranging from the child-on-a-swing problem to quantum limited amplifiers, to optical frequency combs, and to optomechanical sensors used in the LIGO experiment. The course will combine theoretical lectures and the study of important experiments through literature.

The students will receive an extended lecture summary as well as numerous MATHEMATICA and Python scripts, including QuTiP notebooks. These tools will enable them to apply analytical and numerical methods to a wide range of systems beyond the duration of the course.

**Prerequisites / notice**
The students should be familiar with wave mechanics as well as second quantization. Following the course requires a laptop with Python and MATHEMATICA installed.

### 402-0845-80L Scattering Amplitudes in Quantum Field Theories

<table>
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<tr>
<th><strong>W</strong></th>
<th>6 credits</th>
<th><strong>2V+1U</strong></th>
<th>University lecturers</th>
</tr>
</thead>
</table>

**Abstract**
This course provides a pedagogical introduction to an advanced topic in Quantum Field Theories, which has undergone a tremendous progress in the new millennium: scattering amplitudes and on-shell methods.

**Objective**
Students that complete the course will be able to understand the basics of the modern methods to compute scattering amplitudes, to perform simple calculations and to read modern publications on this research field.

**Content**
This course covers the basic concepts of:
- spinor helicity formalism
- colour decompositions
- BCFW on-shell recursion relations
- BCJ colour-kinematics duality
- Feynman integrals: IBPs and differential equations
- analytic and algebraic structure of loop-level amplitudes:
  - Hop algebra, symbols and coproducts
  - multiple polylogarithms (a.k.a. as iterated integrals on the Riemann sphere)
  - Steinnmann relations
  - coaction principle
  - elliptic and modular-form integrals (a.k.a. as iterated integrals on the torus)

**Lecture notes**
Will be provided at the Moodle site for the course.

**Literature**
A basic knowledge of Feynman rules in scalar field theories and in Yang-Mills theory is assumed.

**Prerequisites / notice**
OFT-I and Introduction to Quantum ChromoDynamics are highly recommended.

### 402-0886-00L Quantum Chromodynamics

<table>
<thead>
<tr>
<th><strong>W</strong></th>
<th>6 credits</th>
<th><strong>2V+1U</strong></th>
<th>T. K. Gehrmann</th>
</tr>
</thead>
</table>

**Abstract**
The course presents the quantum field theory of the strong interaction (quantum chromodynamics, QCD) and discusses its applications to particle physics observables.

**Objective**
The course aims to familiarize its students with the concepts and applications of QCD and to introduce them to modern techniques for computations in QCD.

**Content**
Contents:
- Review of non-Abelian gauge theories and their quantization
- Spinor-helicity formalism
- Renormalization of QCD and running coupling constant
- Basic strong interaction processes
- Perturbation theory techniques: loops and phase space
- QCD perturbation theory and applications
- Proton structure in QCD
- Resummation of large logarithmic corrections
- Effective field theories
- Non-perturbative methods

**Prerequisites / notice**
The course assumes prior knowledge of the content of the quantum field theory 1+2 lectures.

### 402-0845-61L Effective Field Theories for Particle Physics

<table>
<thead>
<tr>
<th><strong>W</strong></th>
<th>6 credits</th>
<th><strong>2V+1U</strong></th>
<th>P. Stoffer</th>
</tr>
</thead>
</table>

**Abstract**
This course provides a pedagogical introduction to an advanced topic in Quantum Field Theories, which has undergone a tremendous progress in the new millennium: scattering amplitudes and on-shell methods.

**Objective**
The students will be able to understand the basics of the modern methods to compute scattering amplitudes, to perform simple calculations and to read modern publications on this research field.

**Content**
This course covers the basic concepts of:
- spinor helicity formalism
- colour decompositions
- BCFW on-shell recursion relations
- BCJ colour-kinematics duality
- Feynman integrals: IBPs and differential equations
- analytic and algebraic structure of loop-level amplitudes:
  - Hop algebra, symbols and coproducts
  - multiple polylogarithms (a.k.a. as iterated integrals on the Riemann sphere)
  - Steinnmann relations
  - coaction principle
  - elliptic and modular-form integrals (a.k.a. as iterated integrals on the torus)

**Lecture notes**
Will be provided at the Moodle site for the course.

**Literature**
A basic knowledge of Feynman rules in scalar field theories and in Yang-Mills theory is assumed.

**Prerequisites / notice**
OFT-I and Introduction to Quantum ChromoDynamics are highly recommended.
Abstract
The focus of the course is on Effective Field Theories (EFTs) and their interplay with dispersion theory. These topics will be discussed both in general terms and with specific phenomenological applications in the context of physics beyond the Standard Model, effective description of the weak interaction, as well as the description of non-perturbative strong interaction at low energies.

Objective
This course covers the basic concepts of effective field theories (EFTs) and dispersion theory. We will start by introducing the core concept of constructing EFTs and apply them to the low-energy description of the weak interaction and the effective description of heavy physics beyond the Standard Model.

In the next part of the course, we will discuss Chiral Perturbation Theory (ChPT), the low-energy effective theory of Quantum Chromodynamics (QCD). We will briefly discuss the application of this concept to describe a class of theories beyond the SM in which the SM Higgs arises as a composite state of a new confining sector.

The second focus of the course is on dispersion theory and its interplay with EFTs. We will discuss how to make use of the constraints from unitarity of the S-matrix and analyticity of scattering amplitudes, in order to extend the range of validity of the theoretical description compared to pure EFT methods. We will also discuss how to obtain constraints on EFT parameters from unitarity and analyticity. We will discuss the application of these methods both in the context of low-energy strong interaction and physics beyond the Standard Model.

Content
- Introduction to Effective Field Theories
- Decoupling and matching
- Renormalization group resummation
- The Standard Model Effective Field Theory (SMEFT)
- Chiral Lagrangians
- Uniquity of the S-matrix
- Analyticity and dispersion relations

Prerequisites / notice
QFT-I (mandatory) and QFT-II (highly recommended)

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### Selection: Astrophysics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0490-00L</td>
<td>Advanced Methods in Quantum Many-Body Theory</td>
<td>W</td>
<td>8 credits</td>
<td>3V+1U</td>
<td>E. Demler</td>
</tr>
<tr>
<td>402-0713-00L</td>
<td>Astro-Particle Physics I</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>A. Biland</td>
</tr>
<tr>
<td>402-0393-00L</td>
<td>Theoretical Cosmology and Different Aspects of Gravity</td>
<td>W</td>
<td>8 credits</td>
<td>4V</td>
<td>L. Heisenberg</td>
</tr>
</tbody>
</table>

Abstract
Advanced theoretical methods for analyzing quantum many-body systems will be reviewed. We will discuss equilibrium Green's functions, Keldysh formalism for nonequilibrium phenomena, variational approaches. Specific models that will be considered include systems with dissipation, polaron, interacting electrons, electron-phonon systems, transport in mesoscopic systems, superconductivity, cavity QED approaches.

Objective
Successful students know:
- experimental methods to measure cosmic ray particles over full energy range
- current knowledge about the composition of cosmic ray
- possible cosmic acceleration mechanisms
- correlation between astronomical object classes and cosmic accelerators
- information about our galaxy and cosmology gained from observations of cosmic ray

Content
First semester (Astro-Particle Physics I):
- definition of 'Astro-Particle Physics'
- important historical experiments
- chemical composition of the cosmic rays
- direct observations of cosmic rays
- indirect observations of cosmic rays
- 'extended air showers' and 'cosmic muons'
- 'knee' and 'ankle' in the energy spectrum
- the 'anti-matter problem' and the Big Bang
- 'cosmic accelerators'

Lecture notes
See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/

Literature
See lecture home page: http://ihp-lx2.ethz.ch/AstroTeilchen/
Astronomical techniques and observing strategies are presented with a particular emphasis on currently available professional telescopes of the European Southern Observatory.

Objective

The course shall provide a basic understanding of the potential and limitation of different types of modern astronomical observations for early career researchers. The course will present technical aspects which are important to prepare, to carry out and to calibrate different types of astronomical measurements: photometry, spectroscopy, astrometry, polarimetry and others. Many practical examples will be discussed including methods for the detection of physical samples of cosmic dust. Also scientific aspects of instrumental projects and observational programs are addressed. An opportunity to contribute to solar spacecraft operations will be available during the course.

Content

1. Introduction: research projects in astronomical observations
2. Observables: electromagnetic radiation, particles
3. Optical telescopes: Optics, types, mechanical concepts, examples
4. Detectors: CCDs, IR detectors, basic data reduction steps
5. Photometry: signal extraction, calibration, faint sources, etc.
6. Spectroscopy: spectographs, calibration, spectral features
7. Introduction to solar space instrumentation
8. Space observations of cosmic dust: introduction, remote sensing, in situ instruments, sample return, calibration, data analysis and practical examples
9. Speckles and adaptive optics: atmosphere, AO-systems
10. Polarimetry: measuring principles
11. Interferometry

Notes will be distributed.

Literature


Earth - A (Unique?) Habitable Planet

While thousands of extrasolar planets are known to orbit stars other than the Sun, Earth is - until now - the only planet known to be habitable. This lecture takes an interdisciplinary view on Earth as a habitable planet, how it formed, evolved, allowed life to flourish, and how its future might look like. Would we be able to identify another Earth-like planet amongst the population of exoplanets?

Objective

Attending students will
- understand Earth place in the cosmos
- learn tools to discern the history of Earth and other planets
- explore the origin and co-evolution of Earth and life
- put Earth in context with extrasolar planets

Content

This lecture focuses on our home planet - Earth - from an interdisciplinary perspective. As the search for habitable - and potentially even inhabitable - extrasolar planets is one of the most dynamic research fields in modern astrophysics, understanding what makes a planet habitable is a topic of increasing importance; and a highly interdisciplinary topic. In broad brushes, this lecture will discuss the building blocks of planetary systems and their formation, how we can learn about the history of Earth and other planets, what major epochs we can identify over the course of Earth’s 4.5 billion year history, when life arose on Earth and what impact it had on Earth’s evolution, how the future Earth might look like, and - last but certainly not least - how we can search for an Earth-like planet in our cosmic neighbourhood and what our chances are to be successful.

Confirmed speakers include:
21.09.: Prof. Sascha P. Quanz (ETH Zürich); Professor for Exoplanets
28.09.: Dr. Anna Kubik (ETH Zürich); Senior Scientist for Orbital Dynamics
12.10.: Dr. Andrea Forier (University of Bern); CH/EOPS Instrument Scientist
19.10.: Prof. Volker Gass (EPFL Lausanne); Director of Space Innovation
26.10.: Dr. Hendrik Kolvenbach (ETH Zürich); Postdoctoral Researcher for Space Robotics
02.11.: Deborah Müller (RUAG Space); Director of Innovation & Business Development
16.11. & 21.12.: Prof. Claude Nicollier (EPFL Lausanne); Professor Emeritus, EPFL and former Astronaut
23.11.: Dr. Adrian Glauser (ETH Zürich); Senior Scientist for Astronomical Instrumentation
30.11.: Prof. Louise Harra (ETH Zürich); Professor of Solar Astrophysics
17.12.: Prof. Didier Queloz (ETH Zürich / Cambridge); Professor for Exoplanets

Planet Formation

This course reviews the formation processes of terrestrial- and gaseous planets, and their moons. It provides a basic understanding on how our Solar System came to be, and how other planetary systems form, as well as how/when planets & moons can be habitable places for life.

Objective

Overview the state of the art planet- and moon formation models and identify open questions in the field. Understanding the formation process of planetary systems, and the formation of habitable worlds.
Why is energy important for life and our society?

Astrophysics of Planet Formation
The Physics of Energy, R.L. Jaffe, W. Taylor, 2018

1) Planet types
2) The Solar System planets
3) Extrasolar Planets
4) The protoplanetary disk where planets are forming. The initial conditions for planet formation.
5) The formation of the building blocks of planets (so-called "planetesimals")
6) Terrestrial Planet formation
7) Formation models of giant planets
8) Formation of moons
9) Evolution of planetary systems, orbital evolution of planets, resonances, planet-disk interactions
10) Origin of life, habitability, astrobiology

Our understanding of the universe has made great progress recently thanks to the combination of several cosmological probes such as the cosmic microwave background, galaxy clustering, gravitational lensing, and supernovae. After a review of cosmology, this course will cover the physics of these different probes along with their application, combination and use to measure cosmological parameters.

The objective of this course is to provide an understanding of the physics, application and combination of cosmological probes, and highlight current research topics.

The objective is to learn about field theoretical techniques applied to cosmology.

10) Origin of life, habitability, astrobiology
9) Evolution of planetary systems, orbital evolution of planets, resonances, planet-disk interactions
8) Formation of moons
7) Formation models of giant planets
6) Terrestrial Planet formation
5) The formation of the building blocks of planets (so-called "planetesimals")
4) The protoplanetary disk where planets are forming. The initial conditions for planet formation.
3) Extrasolar Planets
2) The Solar System planets
1) Planet types

Passive elements, linear complex networks, transmission lines, simulation of analog circuits (SPICE), semiconductor elements: diodes, bipolar and field-effect transistors, basic amplifier circuits, small signal analysis, differential amplifiers, noise in analog circuits, operational amplifiers, feedback and stability in amplifiers, oscillators, ADCs and DACs, introduction in CMOS technology.

The lecture provides the basic knowledge necessary to understand, design and simulate analog electronic circuits. In the exercises, the concepts can be experienced in a hands-on manner. Every student has the opportunity to go through all steps of an electronic design cycle. Those include designing schematics, generating a printed circuit board layout, and the realization of a soldered prototype.

Prerequisites / notice
No prior knowledge in electronics is required.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0737-00L</td>
<td>Energy and Sustainability in the 21st Century (Part I)</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>P. Morf</td>
</tr>
</tbody>
</table>

The energy transition and decarbonisation – How is your 2040, 2050?

Building and Mobility – new technologies, new Ways of life?

Climate change, decarbonisation – how much time do we have?

Economics of energy, learning curves, technology assessments and Innovation.

The energy transition and decarbonisation – How is your 2040, 2050?

The energy system and the environmental interactions.

Training of scientific and multi-disciplinary methods, approaches and their limits in the exercises and discussions.

Prerequisites / notice
Basics of Physics applied to Energy and Energy Technology.
Investigation on current problems (and possible solutions) related to the energy system and the environmental interactions.

Lecture notes
Web page: http://ihp-ix2.ethz.ch/energy21/index.html

Literature
The Physics of Energy, R.L. Jaffe, W. Taylor, 2018
Clean Disruption of Energy and Transportation, T. Seba 2014
Energy and Civilization: A History, V. Šmil, 2018

Prerequisites / notice
No prerequisites. Max. 20 participants.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>402-0371-62L</td>
<td>Cosmological Probes</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>A. Refregier</td>
</tr>
</tbody>
</table>

Max. 20 participants.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0363-00L</td>
<td>Effective Field Theory in Cosmology</td>
<td>W</td>
<td>6</td>
<td>2V+1U</td>
<td>L. Senatore</td>
</tr>
</tbody>
</table>

Number of participants limited to 40.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>402-0247-00L</td>
<td>Electronics for Physicists I (Analogue)</td>
<td>W</td>
<td>4</td>
<td>2V+2P</td>
<td>G. Bison, W. Erdmann</td>
</tr>
</tbody>
</table>
As information technology continues its fast-paced evolution, solid-state devices and systems increase in complexity. Engineers and scientists are thus increasingly facing the need to model and simulate their problems numerically where analytic textbook solution cease to exist. Moreover, boundaries between traditional disciplines are harder to maintain, as a proper description of the system might involve phenomena from several domains. Examples include—but not limited to—mechatronics which relies on mechanical, electrical and electronic engineering, and transducers (sensors and actuators) which are by definition devices that convert signals from one physical domain to another. Simulation platforms such as Comsol Multiphysics have truly opened the way to easy multi-domain numerical simulation, offering tools that cover all operations from geometry definition, to meshing, to physics and boundary conditions setting to simulation and result post-processing and analysis in a unified, domain-independent fashion. However, this high degree of freedom has its price, as unexperienced users will soon find themselves in front of frustrating error messages or incomprehensible results. It is the role of this course to show how to properly set up a problem by exposing common misconceptions and pitfalls in multiphysics modeling. Good examples will mainly come from the fields of mechanics (continuum mechanics), electromagnetism (Maxwell equations), heat transport (Fourier equation) and combinations of these domains.

### Content
- Recap of ordinary and partial differential equations (ODEs and PDEs) concepts
- Existence and uniqueness of solutions; well- and ill-posed problems
- Time integration and (non)linear solvers
- Boundary conditions and constraints
- Approximate and simplified formulations; domains of applicability
- Discretization and numerical solutions for differential equations
- Solution-appropriate meshing; multiscale, local/global adaptive meshing
- Geometry simplification
- Model order reduction, coarsening
- Coupling and segregation/decoupling of multiphysics

### Literature
- Analog VLSI Circuits and Principles; various publications.
- Comsol Multiphyics will be utilized to apply the concepts learned during the lectures to solve exercises.

### Selection: Neuroinformatics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1033-00L</td>
<td>Multiphysics Modeling and Simulation</td>
<td>W</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>C. I. Roman</td>
</tr>
</tbody>
</table>

### Objective
- Recap of ordinary and partial differential equations (ODEs and PDEs) concepts
- Existence and uniqueness of solutions; well- and ill-posed problems
- Time integration and (non)linear solvers
- Boundary conditions and constraints
- Approximate and simplified formulations; domains of applicability
- Discretization and numerical solutions for differential equations
- Solution-appropriate meshing; multiscale, local/global adaptive meshing
- Geometry simplification
- Model order reduction, coarsening
- Coupling and segregation/decoupling of multiphysics

### Content
- Recap of ODEs and PDEs concepts
- Boundary conditions and constraints
- Discretization and numerical solutions for differential equations
- Solution-appropriate meshing; multiscale, local/global adaptive meshing
- Geometry simplification

### Literature
- Analog VLSI Circuits and Principles; various publications.

### Prerequisites / notice
- Background in basics of semiconductor physics helpful, but not required.

### Selection: Neuroinformatics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-1037-00L</td>
<td>Introduction to Neuroinformatics</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U+1A</td>
<td>V. Mante, M. Cook, B. Grewe, G. Indiveri, D. Kiper, W. von der Behrens</td>
</tr>
</tbody>
</table>

### Objective
- Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neural computation. The goal of this introductory course is to introduce the monocultures of physics, math, computer science, engineering, biology, psychology, and even philosophy and history, to discover the engravings and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of feedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor information in neural networks.

### Selection: Biophysics, Physical Chemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>551-1601-00L</td>
<td>Biophysics of Biological Macromolecules</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>F. Ailain, S. Jonas</td>
</tr>
</tbody>
</table>

**Abstract**
This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students. The topics include: The molecules of life - properties of biological macromolecules. Discussion of structure and function of proteins, quantitative description molecular interactions and of enzyme function; Introduction to methods to study biological macromolecules: purification techniques, optical spectroscopy, X-ray crystallography, electron microscopy (EM) and nuclear magnetic resonance (NMR) spectroscopy. Introduction to the genetic system of E.coli bacteria: DNA, RNA and protein biosynthesis (transcription and translation) and biotechnological applications.

**Objective**
This lecture course targets physics students and students of interdisciplinary sciences (major physics) for their education in biophysics. In this course the basics of molecular biology are presented bearing in mind the special interests of the physics students.

**Content**
Additional documentation in support of text book
Small classes with active participation of students

### Selection: Medical Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>402-0341-00L</td>
<td>Medical Physics I</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U</td>
<td>P. Manser</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the fundamentals of medical radiation physics. Functional chain due to radiation exposure from the primary physical effect to the radiobiological and medically manifest secondary effects. Dosimetric concepts of radiation protection in medicine. Mode of action of radiation sources used in medicine and its illustration by means of Monte Carlo simulations.

**Objective**
Understanding the functional chain from primary physical effects of ionizing radiation to clinical radiation effects. Dealing with dose as a quantitative measure of medical exposure. Getting familiar with methods to generate ionizing radiation in medicine and learn how they are applied for medical purposes. Eventually, the lecture aims to show the students that medical physics is a fascinating and evolving discipline where physics can directly be used for the benefits of patients and the society.

**Content**
The lecture is covering the basic principles of ionizing radiation and its physical and biological effects. The physical interactions of photons as well as of charged particles will be reviewed and their consequences for medical applications will be discussed. The concept of Monte Carlo simulation will be introduced in the excercises and will help the student to understand the characteristics of ionizing radiation in simple and complex situations. Fundamentals in dosimetry will be provided in order to understand the physical and biological effects of ionizing radiation. Deterministic as well as stochastic effects will be discussed and fundamental knowledge about radiation protection will be provided. In the second part of the lecture series, we will cover the generation of ionizing radiation. By this means, the x-ray tube, the clinical linear accelerator, and different radioactive sources in radiology, radiotherapy and nuclear medicine will be addressed. Applications in radiology, nuclear medicine and radiotherapy will be described with a special focus on the physics underlying these applications.

**Lecture notes**
A script will be provided.

**Prerequisites / notice**
For students of the MAS in Medical Physics (Specialization A) the performance assessment is offered at the earliest in the second year of the studies.

| 402-0674-00L | Physics in Medical Research: From Atoms to Cells | W    | 6 credits | 2V+1U | B. K. R. Müller |

**Abstract**
Scanning probe and diffraction techniques allow studying activated atomic processes during early stages of epitaxial growth. For quantitative description, rate equation analysis, mean-field nucleation and scaling theories are applied on systems ranging from simple metallic to complex organic materials. The knowledge is expanded to optical and electronic properties as well as to proteins and cells.
Objective

The lecture series is motivated by an overview covering the skin of the crystals, roughness analysis, contact angle measurements, protein absorption/activity and monocyte behaviour.

As the first step, real structures on clean surfaces including surface reconstructions and surface relaxations, defects in crystals are presented, before the preparation of clean metallic, semiconducting, oxidic and organic surfaces are introduced.

The atomic processes on surfaces are activated by the increase of the substrate temperature. They can be studied using scanning tunneling microscopy (STM) and atomic force microscopy (AFM). The combination with molecular beam epitaxy (MBE) allows determining the sizes of the critical nuclei and the other activated processes in a hierarchical fashion. The evolution of the surface morphology is characterized by the density and size distribution of the nanostructures that could be quantified by means of the rate equation analysis, the mean-field nucleation theory, as well as the scaling theory. The surface morphology is further characterized by defects and nanostructure's shapes, which are based on the strain relieving mechanisms and kinetic growth processes.

High-resolution electron diffraction is complementary to scanning probe techniques and provides exact mean values. Some phenomena are quantitatively described by the kinematic theory and perfectly understood by means of the Ewald construction. Other phenomena need to be described by the more complex dynamical theory. Electron diffraction is not only associated with elastic scattering but also inelastic excitation mechanisms that reflect the electronic structure of the surfaces studied. Low-energy electrons lead to phonon and high-energy electrons to plasmon excitations. Both effects are perfectly described by dipole and impact scattering.

Thin-films of rather complex organic materials are often quantitatively characterized by photons with a broad range of wavelengths from ultra-violet to infra-red light. Asymmetries and preferential orientations of the (anisotropic) molecules are verified using the optical dichroism and second harmonic generation measurements. Recently, ellipsometry has been introduced to on-line monitor film thickness, and roughness with sub-nanometer precision. These characterisation techniques are vital for optimising the preparation of medical implants.

Cell-surface interactions are related to the cell adhesion and the contractile cellular forces. Physical means have been developed to quantify these interactions. Other physical techniques are introduced in cell biology, namely to count and sort cells, to study cell proliferation and metabolism and to determine the relation between cell morphology and function.

X rays are more and more often used to characterise the human tissues down to the nanometer level. The combination of highly intense beams only some micrometers in diameter with scanning enables spatially resolved measurements and the determination of tissue's anisotropies of biopsies.

### Selection: Environmental Physics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1239-00L</td>
<td>Aerosols I: Physical and Chemical Principles</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>M. Gysel Beer, D. Bell, E. Weingartner</td>
</tr>
</tbody>
</table>

**Abstract**

Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

**Objective**

Physical and chemical principles:

- The students...
- know the processes and physical laws of aerosol dynamics.
- understand the thermodynamics of phase equilibria and chemical equilibria.
- know the photo-chemical formation of particulate matter from inorganic and organic precursor gases.

Experimental methods:

- The students...
  - know the most important chemical and physical measurement instruments.
  - understand the underlying chemistry and physics.

Environmental impacts:

- The students...
  - know the major sources of atmospheric aerosols, their chemical composition and key physical properties.
  - know the most important climate impacts of atmospheric aerosols.

- are aware of the health impacts of atmospheric aerosols.

**Lecture notes**


**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td>Project Management</td>
<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
<td>Customer Orientation</td>
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<td></td>
<td>Leadership and Responsibility</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>not assessed</td>
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<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tbody>
</table>
Boundary Layer Meteorology

This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

Webpage for course: https://iac.ethz.ch/edu/courses/bachelor/vertiefung/atmospheric-physics.html

Students are able to:
- explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics.
- evaluate the significance of clouds and aerosol particles for artificial weather modification.

The course starts by introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to classify radiosondes with the help of the thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15387


50% of the time we use the concept of "flipped classroom" (en.wikipedia.org/wiki/Flipped_classroom), which we introduce at the beginning.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is a additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. Participation is recommended but voluntary.

Domain A - Subject-specific Competencies
- Concepts and Theories

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
- Critical Thinking
- Self-direction and Self-management

Dynamics of Large-Scale Atmospheric Flow

This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Prerequisites / notice
- Physics I, II, Environmental Fluid Dynamics

Dynamics of large-scale atmospheric flow

651-4053-05L

Boundary Layer Meteorology

The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts.

Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

- Introduction
- Turbulence
- Statistical treatment of turbulence, turbulent transport
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Spectral characteristics
- Concepts for non-ideal boundary layer conditions

Available (i.e. in English)


Umwelt-Fluidynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

Selection: Mathematics

Number Title Type ECTS Hours Lecturers
401-3531-00L Differential Geometry I W 10 credits 4V+1U J. Serra
This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, series of independent random variables, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).
- Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

Lecture notes

will be available in electronic form.
Literature
H. Bauer, Probability Theory, de Gruyter 1996
J. Jacod and P. Protter, Probability essentials, Springer 2004
A. Klenke, Wahrscheinlichkeitstheorie, Springer 2006
D. Williams, Probability with martingales, Cambridge University Press 1991

401-3621-00L Fundamentals of Mathematical Statistics W 10 credits 4V+1U S. van de Geer
Abstract
The course covers the basics of inferential statistics.

>>> Selection: Electives at the University of Zurich
University of Zurich lecturers explicitly recommended the following courses also to physics students at ETH Zurich.
Recognition of the corresponding external ECTS credits has to be granted by the Director of Studies. Submit your request to the Study Administration (www.phys.ethz.ch/studies/study-administration.html).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>401-7851-00L</td>
<td>Theoretical Astrophysics (University of Zurich)</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>University lecturers</td>
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<tr>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: AST512</td>
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<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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<tr>
<td>Abstract</td>
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<tr>
<td>This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.</td>
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<tr>
<td>Content</td>
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<tr>
<td>This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.</td>
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<tr>
<td>Literature</td>
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<tr>
<td>Course Materials:</td>
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<tr>
<td>1- The Physics of Astrophysics, Volume 1: Radiation by Frank H. Shu</td>
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<td>2- The Physics of Astrophysics, Volume 2: Gas Dynamics by Frank H. Shu</td>
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<td>3- Foundations of radiation hydrodynamics, Dimitri Mihalas and Barbara Weibel-Mihalas</td>
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<td>4- Radiative Processes in Astrophysics, George B. Rybicki and Alan P. Lightman</td>
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<td>5- Galactic Dynamics, James Binney and Scott Tremaine</td>
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<tr>
<td>Prerequisites / notice</td>
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<tr>
<td>This is a full black board ad chalk experience for students with a strong background in mathematics and physics.</td>
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<tr>
<td>Prerequisites:</td>
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<tr>
<td>Introduction to Astrophysics</td>
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<tr>
<td>Mathematical Methods for the Physicist</td>
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<tr>
<td>Quantum Mechanics</td>
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<td>(All preferred but not obligatory)</td>
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<td>Prior Knowledge:</td>
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<tr>
<td>Mechanics</td>
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<tr>
<td>Quantum Mechanics and atomic physics</td>
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<tr>
<td>Thermodynamics</td>
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<td>Fluid Dynamics</td>
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<td>Electrodynamics</td>
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</table>

| 401-7855-00L | Computational Astrophysics (University of Zurich) | W | 6 credits | 2V | L. M. Mayer |
   | No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: AST245 |
   | Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html |
   | Objective |
   | Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes |
   | Content |
   | 1. Integration of ODE, Hamiltonians and Symplectic integration techniques, time adaptivity, time reversibility |
   | 2. Large-N gravity calculation, collisionless N-body systems and their simulation |
   | 3. Fast Fourier Transform and spectral methods in general |
   | 4. Eulerian Hydrodynamics: Upwinding, Riemann solvers, Limiters |
   | 5. Lagrangian Hydrodynamics: The SPH method |
   | 6. Resolution and instabilities in Hydrodynamics |
   | 7. Initial Conditions: Cosmological Simulations and Astrophysical Disks |
   | 8. Physical Approximations and Methods for Radiative Transfer in Astrophysics |
   | Literature |
   | Galactic Dynamics (Binney & Tremaine, Princeton University Press), |
   | Computer Simulation using Particles (Hockney & Eastwood CRC press), |
   | Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh) |
   | Prerequisites / notice |
   | Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial |

| 402-6394-00L | Advanced Topics of Theoretical Cosmology (University of Zurich) | W | 4 credits | 1V | J. Yoo |
   | No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: AST802 |
   | Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html |
### General Electives

Students may choose General Electives from the entire course programme of ETH Zurich - with the following restrictions: courses that belong to the first or second year of a Bachelor curriculum at ETH Zurich as well as courses from GESS "Science in Perspective" are not eligible here.

The following courses are explicitly recommended to physics students by their lecturers. (Courses in this list may be assigned to the category “General Electives” directly in myStudies. For the category assignment of other eligible courses keep the choice “no category” and take contact with the Study Administration (www.phys.ethz.ch/studies/study-administration.html) after having received the credits.)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>529-0433-00L</td>
<td>Advanced Physical Chemistry: Statistical Thermodynamics</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>R. Riek, J. Richardson</td>
</tr>
<tr>
<td>151-0163-00L</td>
<td>Nuclear Energy Conversion</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>A. Manera</td>
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<tr>
<td>151-0103-00L</td>
<td>Fluid Dynamics II</td>
<td>W</td>
<td>3</td>
<td>2V+1U</td>
<td>P. Jenny</td>
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<tr>
<td>151-0532-00L</td>
<td>Nonlinear Dynamics and Chaos I</td>
<td>W</td>
<td>4</td>
<td>2V+2U</td>
<td>G. Haller</td>
</tr>
</tbody>
</table>
The course builds upon three parts:

I. Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II. Theoretical basis of statistical mechanics and kinetic equations.
III. Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   - Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   - Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   - Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   - Relativistic fluid dynamics; flows with phase transitions.

Lecture notes on the theoretical parts of the course will be made available. Selected original and review papers are provided for some of the lectures on advanced topics. Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.
Introduction to Plasmonics

1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)

2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)

3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models

4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

Handouts and lecture notes available online.

Lecture notes and handouts available online.

Prerequisites: Fluiddynamics I, Numerical Mathematics, programming skills.

Literature

- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Metamaterials
- Sensing
- Enhanced spectroscopy
- Sensing
- Metamaterials

Prerequisites / notice

151-0107-20L High Performance Computing for Science and Engineering (HPCE) I

Abstract

This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.

Objective

Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Content

- Basic electromagnetic theory
- Optical properties of metals
- Surface plasmon polaritons on surfaces
- Surface plasmon polariton propagation
- Localized surface plasmons
- Applications of Plasmonics
- Waveguides
- Extraordinary optical transmission
- Enhanced spectroscopy
- Sensing
- Metamaterials

Lecture notes

Class notes and handouts

Literature


Prerequisites / notice

151-0911-00L Introduction to Plasmonics

Abstract

This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.

Objective

Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Content

- Basic electromagnetic theory
- Optical properties of metals
- Surface plasmon polaritons on surfaces
- Surface plasmon polariton propagation
- Localized surface plasmons
- Applications of Plasmonics
- Waveguides
- Extraordinary optical transmission
- Enhanced spectroscopy
- Sensing
- Metamaterials

Lecture notes

Class notes and handouts

Literature


Prerequisites / notice

115-0107-20L High Performance Computing for Science and Engineering (HPCE) I

Abstract

This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.

Objective

Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

Content

- Basic electromagnetic theory
- Optical properties of metals
- Surface plasmon polaritons on surfaces
- Surface plasmon polariton propagation
- Localized surface plasmons
- Applications of Plasmonics
- Waveguides
- Extraordinary optical transmission
- Enhanced spectroscopy
- Sensing
- Metamaterials

Lecture notes

Class notes and handouts

Literature


Prerequisites / notice

Mind the enrolment deadlines at UZH:

- Autumn Semester 2021

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: INI410
This seminar reviews the philosophical and phenomenological as well as the neurobiological aspects of consciousness. The subjective features of consciousness are explored, and modern research into its neural substrate, particularly in the visual domain, is explained. Emphasis is placed on students developing their own thinking through a discussion-centered course structure.

The course's goal is to give an overview of the contemporary state of consciousness research, with emphasis on the contributions brought by modern cognitive neuroscience. We aim to clarify concepts, explain their philosophical and scientific backgrounds, and to present experimental protocols that shed light on a variety of consciousness related issues.

The course includes discussions of scientific as well as philosophical articles. We review current schools of thought, models of consciousness, and proposals for the neural correlate of consciousness (NCC).

Since we are all experts on consciousness, we expect active participation and discussions!

**Lecture notes**
None

**Literature**
We display articles pertaining to the issues we cover in the class on the course's webpage.

**Prerequisites / notice**
Since we are all experts on consciousness, we expect active participation and discussions!

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**151-0621-00L**

**Microsystems I: Process Technology and Integration**

- **W 6 credits**
- **3G+3U**
- **M. Haluska, C. Hierold**

Students are introduced to the fundamentals of semiconductors, the basics of micromachining and silicon process technology and will learn about the fabrication of microsystems and -devices by a sequence of defined processing steps (process flow).

Students are introduced to the basics of micromachining and silicon process technology and will understand the fabrication of microsystem devices by the combination of unit process steps ("process flow").

- Introduction to micromachining technology (MST) and micro electro mechanical systems (MEMS)
- Basic silicon technologies: Thermal oxidation, photolithography and etching, diffusion and ion implantation, thin film deposition.
- Specific microsystems technologies: Bulk and surface micromachining, dry and wet etching, isotropic and anisotropic etching, beam and membrane formation, wafer bonding, thin film mechanical properties.

**Application of selected technologies will be demonstrated on case studies.**

**Lecture notes**
Handouts (available online)

- S.M. Sze: Semiconductor Devices, Physics and Technology
- W. Menz, J. Mohr, O.Paul: Microsystem Technology
- Hong Xiao: Introduction to Semiconductor Manufacturing Technology
- T. M. Adams, R. A. Layton: Introductory MEMS, Fabrication and Applications

**Literature**

- S. Kozorke, K. P. Prüßmann

**Prerequisites / notice**
Prerequisites: Physics I and II

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**227-0385-10L**

**Biomedical Imaging**

- **W 6 credits**
- **5G**
- **S. Kozorke, K. P. Prüßmann**

Introduction and analysis of medical imaging technology including X-ray procedures, computed tomography, nuclear imaging techniques using single photon and positron emission tomography, magnetic resonance imaging and ultrasound imaging techniques.

To understand the physical and technical principles underlying X-ray imaging, computed tomography, single photon and positron emission tomography, magnetic resonance imaging, ultrasound and Doppler imaging techniques. The mathematical framework is developed to describe image encoding/decoding, point-spread function/modular transfer function, signal-to-noise ratio, contrast behavior for each of the methods. Matlab exercises are used to implement and study basic concepts.

- X-ray imaging
- Computed tomography
- Single photon emission tomography
- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound/Doppler imaging

**Lecture notes**
Lecture notes and handouts

**Literature**

- Webb A, Smith N.B. Introduction to Medical Imaging; Physics, Engineering and Clinical Applications; Cambridge University Press 2011
- Analysis, Linear Algebra, Physics, Basics of Signal Theory, Basic skills in Matlab programming

**Prerequisites / notice**

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**227-0386-00L**

**Biomedical Engineering**

- **W 4 credits**
- **3G**
- **J. Váròs, S. J. Ferguson, S. Kozorke, M. P. Wolf, M. Zenobi-Wong**

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The focus is on learning the concepts that govern common medical instruments and the most important organs from an engineering point of view. In addition, the most recent achievements and trends of the field of biomedical engineering are also outlined.

Introduction into selected topics of biomedical engineering as well as their relationship with physics and physiology. The course provides an overview of the various topics of the different tracks of the biomedical engineering master course and helps orienting the students in selecting their specialized classes and project locations.


Practical and theoretical exercises in small groups in the laboratory.

**Lecture notes**
Introduction to Biomedical Engineering by Enderle, Banchard, and Bronzino

**AND**

https://ibb.ethz.ch/education/biomedical-engineering.html

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**227-0965-00L**

**Micro and Nano-Tomography of Biological Tissues**

- **W 4 credits**
- **3G**
- **M. Stamparoni, F. Marone Welford**

The lecture introduces the physical and technical know-how of X-ray tomographic microscopy. Several X-ray imaging techniques (absorption-, phase- and darkfield contrast) will be discussed and their use in daily research, in particular biology, is presented. The course discusses the aspects of quantitative evaluation of tomographic data sets like segmentation, morphology and statistics.

Introduction to the basic concepts of X-ray tomographic imaging, image analysis and data quantification at the micro and nano scale with particular emphasis on biological applications.

Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied
research that addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical
simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer
simulations of the most important devices and of interesting physical effects supplement the lectures.

The course aims at understanding the principle physics of modern semiconductor devices, the foundations of the physical
modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics
and device physics is provided.

The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model,
hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers,
recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-
insulator-semiconductor structure, and heterojunctions.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor,
resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an
advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

The script (in book style) can be downloaded from: https://lis-students.ee.ethz.ch/lectures/
Lecture notes
Literature
Prerequisites / notice
Qualifications: Physics I-II, Semiconductor devices (4. semester),
Mathematics for Engineering, Analytic Geometry, Calculus

227-0157-00L  
Semiconductor Devices: Physical Bases and Simulation  
W 4 credits 3G  
A. Schenk, C. I. Roman

Abstract  
The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical
simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer
simulations of the most important devices and of interesting physical effects supplement the lectures.

Objective  
The course aims at understanding the principle physics of modern semiconductor devices, the foundations of the physical
modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics
and device physics is provided.

Content  
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model,
hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers,
recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-
insulator-semiconductor structure, and heterojunctions.

The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor,
resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an
advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

The script (in book style) can be downloaded from: https://lis-students.ee.ethz.ch/lectures/
Lecture notes
Literature
Prerequisites / notice
Qualifications: Physics I-II, Semiconductor devices (4. semester),
Mathematics for Engineering, Analytic Geometry, Calculus

227-0663-00L  
Nanooptics  
W 6 credits 2V+2U  
M. Frimmer

Abstract  
Nanooptics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied
research enabled by the rapid advance of nanotechnology. Nanooptics embraces topics such as plasmonics, optical antennas, optical
trapping and manipulation, and high/super-resolution imaging and spectroscopy.

Objective  
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Content  
We start with the angular spectrum representation of fields to understand the classical resolution limit. We continue with the theory of
strongly focused light, the point spread function, and resolution criteria of conventional microscopy, before turning to super-resolution
techniques, based on near- and far-fields. We introduce the local density of states and approaches to control spontaneous emission rates
in inhomogeneous environments, including optical antennas. Finally, we touch upon optical forces and their applications in optical
tweezers.

Prerequisites / notice  
Electromagnetic fields and waves (or equivalent)  
Physics I-II

227-0301-00L  
Optical Communication Fundamentals  
W 6 credits 2V+1U+1P  
J. Leuthold

Abstract  
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is
discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system.
This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Objective  
An in-depth understanding on how information is transmitted from source to destination. Also the mathematical framework to describe the
important elements will be passed on. Students attending the lecture will further get involved in critical discussion on societal, economical
and environmental aspects related to the on-going exponential growth in the field of communications.

Content  
* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.


* Chapter 3: The Optical Fiber Channel: Geometrical optics, The wave equations in a fiber, Fiber modes, Fiber propagation, Fiber losses,
Nonlinear effects in a fiber.

* Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error
estimations.

* Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error
correction coding.

* Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, QCDMA.

* Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes
Literature
Prerequisites / notice  


227-0116-00L  
VLSI 1: HDL based design for FPGAs  
W 6 credits 5G  
F. K. Gürkaynak, L. Benini

Abstract  
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high
performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and
automatic synthesis for producing industrial-quality circuits.

Objective  
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable
Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from
architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected
with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality
VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic
Design Automation (EDA) tools.
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Literature
Main course book: "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits" by Michael L. Bushnell and S. Blunier, M. Haluska
C. Hierold

Lecture notes
Textbook and all further documents in English.

Prerequisites / notice
Prerequisites:
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

227-0148-00L VLSI III: Test and Fabrication of VLSI Circuits  W  6 credits 4G  L. Benini
Does not take place this semester.

Abstract
In this course, we will cover how modern microchips are fabricated, and we will focus on methods and tools to uncover fabrication defects, if any, in these microchips. As part of the exercises, students will get to work on an industrial $1 million dollar automated test equipment.

Objective
Learn about modern IC manufacturing methodologies, understand the problem of IC testing. Cover the basic methods, algorithms and techniques to test circuits in an efficient way. Learn about practical aspects of IC testing and apply what you learn in class using a state-of-the-art test system.

Content
In this course we will deal with modern integrated circuit (IC) manufacturing technology and cover topics such as:
- Today’s nanometer CMOS fabrication processes (HKMG).
- Optical and post optical Photolithography.
- Potential alternatives to CMOS technology and MOSFET devices.
- Evolution paths for design methodology.
- Industrial roadmaps for the future evolution of semiconductor technology (ITRS).

If you want to earn money by selling ICs, you will have to deliver a product that will function properly with a very large probability. The main emphasis of the lecture will be discussing how this can be achieved. We will discuss fault models and practical techniques to improve testability of VLSI circuits. At the IIS we have a state-of-the-art automated test equipment (Advantest SoC V93000) that we will make available for in class exercises and projects. At the end of the lecture you will be able to describe state-of-the-art digital integrated circuits such as to make them testable and to use automatic test equipment (ATE) to carry out the actual testing.

During the first weeks of the course there will be weekly practical exercises where you will work in groups of two. For the last 5 weeks of the class students will be able to choose a class project that can be:
- The test of their own chip developed during a previous semester thesis
- Developing new setups and measurement methods in C++ on the tester
- Helping to debug problems encountered in previous microchips by IIS.

Half of the oral exam will consist of a short presentation on this class project.

Lecture notes

Prerequisites / notice
Although this is the third part in a series of lectures on VLSI design, you can follow this course even if you have not visited VLSI I and VLSI II lectures. An interest in integrated circuit design, and basic digital circuit knowledge is required though.

Course website:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

151-0620-00L Embedded MEMS Lab  W  5 credits 3P  C. Hierold, S. Blunier, M. Haluska

Abstract
Practical course: Students are introduced to the process steps required for the fabrication of MEMS (Micro Electro Mechanical System) and carry out the fabrication and testing steps in the clean rooms by themselves. Additionally, they learn the requirements for working in clean rooms. Processing and characterization will be documented and analyzed in a final report. Limited access

Objective
Students learn the individual process steps that are required to make a MEMS (Micro Electro Mechanical System). Students carry out the process steps themselves in laboratories and clean rooms. Furthermore, participants become familiar with the special requirements (cleanliness, safety, operation of equipment and handling hazardous chemicals) of working in the clean rooms and laboratories. The entire production, processing, and characterization of the MEMS is documented and evaluated in a final report.

Content
With guidance from a tutor, the individual silicon microsystem process steps that are required for the fabrication of an accelerometer are carried out:
- Photolithography, dry etching, wet etching, sacrificial layer etching, various cleaning procedures
- Packaging and electrical connection of a MEMS device
- Testing and characterization of the MEMS device
- Written documentation and evaluation of the entire production, processing and characterization

Lecture notes
A document containing theory, background and practical course content is distributed at the Introductory lecture day of the course.

Literature
The document provides sufficient information for the participants to successfully participate in the course.
The course starts with a recapitulation of density operator and product operator formalism with special emphasis on electron-nuclear spin multifunctional ferroic materials: growth and advanced magnetic resonance. This course provides a general introduction into electron microscopy of organic and inorganic materials. In the first part, the basics of structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

Multifunctional Ferroic Materials: Growth and Characterization

The course will explore the growth of (multi-) ferroic oxide thin films. The structural characterization and ferroic state investigation by force microscopy and by laser-optical techniques will be addressed. Oxide electronics device concepts will be discussed.

Objective

Oxide films with a thickness of just a few atoms can now be grown with a precision matching that of semiconductors. This opens up a whole world of functional device concepts and fascinating phenomena that would not occur in the expanded bulk crystal. Particularly interesting phenomena occur in films showing magnetic or electric order or, even better, both of these (multiferroics).

Content

In this course students will obtain an overarching view on oxide epitaxial films and heterostructures design, reaching from their growth by pulsed laser deposition to an understanding of their magnetoelectric functionality from advanced characterization techniques. Students will therefore understand how to fabricate and characterize highly oriented films with magnetic and electric properties not found in nature.

Types of ferroic order, multiferroics, oxide materials, thin-film growth by pulsed laser deposition, molecular beam epitaxy, RF sputtering, structural characterization (reciprocal space - basics-, XRD for thin films, RHEED) epitaxial strain related effects, scanning probe microscopy techniques, laser-optical characterization, oxide thin film based devices and examples.

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book “Spin Dynamics” by Malcolm Levitt.

A script which covers the topics will be distributed in the lecture and will be accessible through the course Moodle.

Advanced Magnetic Resonance

The course is for advanced students and covers selected topics from magnetic resonance spectroscopy. This semester, the lecture will introduce and discuss the dynamics of electron-nuclear spin systems and experiments based on hyperfine interactions in electron paramagnetic resonance (EPR) spectroscopy and dynamic nuclear polarization (DNP) for sensitivity enhancement in NMR.

Objective

The course aims at enabling students to understand and design experiments that are based on hyperfine coupling between electron and nuclear spins. This includes analytical and numerical treatment of spin dynamics as well as instrumental aspects. Additionally, students will learn how to use hyperfine couplings to increase sensitivity in solid state NMR via dynamic nuclear polarization (DNP), with an emphasis on the instrumentation required to perform DNP with magic angle spinning (MAS) NMR.

Content

Based on these foundations, we discuss polarization transfer from the electron to the nuclear spin and back, as well as spin diffusion as a mechanism for polarizing nuclear spins beyond the immediate vicinity of the electron spin. The second half of the course will cover dynamic nuclear polarization (DNP), with a focus on instrumentation required to perform pulsed DNP with magic angle spinning (MAS) at ultra-high magnetic fields. A review of salient interactions in the NMR solid state NMR Hamiltonian, DNP mechanisms, and electron decoupling with MAS will motivate discussions of technology development. Specific technologies to be covered include, but are not limited to, frequency agile gyromotion oscillators, corrugated waveguides, microwave lenses, strategies for creating pulsed and frequency chirped microwave, spherical MAS rotors and supporting stators, high temperature superconductor (HTS) based compact magnets, and radio-frequency circuits for multinuclear spin control and detection.

Prerequisite: A basic knowledge of Magnetic Resonance, e.g. as covered in the Lecture Physical Chemistry IV, or the book “Spin Dynamics” by Malcolm Levitt.

A script which covers the topics will be distributed in the lecture and will be accessible through the course Moodle.

Electron Microscopy in Material Science

A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Abstract

A comprehensive understanding of the interaction of electrons with condensed matter and details on the instrumentation and methods designed to use these probes in the structural and chemical analysis of various materials.

Content

This course provides a general introduction into electron microscopy of organic and inorganic materials. In the first part, the basics of transmission- and scanning electron microscopy are presented. The second part includes the most important aspects of specimen preparation, imaging and image processing. In the third part, recent applications in materials science, solid state physics, structural biology, structural geology and structural chemistry will be reported.

Lecture notes

will be distributed in English

Literature


Erni: Aberration-corrected imaging in transmission electron microscopy, Imperial College Press (2010, and 2nd ed. 2015)

EM-Practical Course in Materials Science

Practical work on TEM, SEM, FIB and APT treatment of typical problems data analysis, writing of a report

Microscopy Training SEM I - Introduction to SEM

Objective
Application of basic electron microscopic techniques to materials science problems
see lecture Electron Microscopy (327-0703-00L)

Prerequisites / notice
Attendance of lecture Electron Microscopy (327-0703-00L) is recommended.
Maximum number of participants 15, work in groups of 3 people.

327-2125-00L

Microscopy Training SEM I - Introduction to SEM

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (http://www scopem.ethz.ch/education/MTP.html).

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
This introductory course on Scanning Electron Microscopy (SEM) emphasizes hands-on learning. Using ScopeM SEMs, students have the opportunity to study their own samples (or samples provided) and solve practical problems by applying knowledge acquired during the lectures. At the end of the course, students will be able to apply SEM for their (future) research projects.

Objective
- Set-up, align and operate a SEM successfully and safely.
- Understand important operational parameters of SEM and optimize microscope performance.
- Explain different signals in SEM and obtain secondary electron (SE) and backscatter electron (BSE) images.
- Operate the SEM in low-vacuum mode.
- Make use of EDX for semi-quantitative elemental analysis.
- Prepare samples with different techniques and equipment for imaging and analysis by SEM.

Content
During the course, students learn through lectures, demonstrations, and hands-on sessions how to setup and operate SEM instruments, including low-vacuum and low-voltage applications.

This course gives basic skills for students new to SEM. At the end of the course, students are able to align an SEM, to obtain secondary electron (SE) and backscatter electron (BSE) images and to perform energy dispersive X-ray spectroscopy (EDX) semi-quantitative analysis. Emphasis is put on procedures to optimize SEM parameters in order to best solve practical problems and deal with a wide range of materials.

Lectures:
- Introduction on Electron Microscopy and instrumentation
- electron sources, electron lenses and probe formation
- beam/specimen interaction, image formation, image contrast and imaging modes.
- sample preparation techniques for EM
- X-ray micro-analysis (theory and detection), qualitative and semi-quantitative EDX and point analysis, linescan and spectral mapping

Practicals:
- Brief description and demonstration of the SEM microscope
- Practice on image formation, image contrast (and image processing)
- Student participation on sample preparation techniques
- Scanning Electron Microscopy lab exercises: setup and operate the instrument under various imaging modalities
- Practice on real-world samples and report results

Lecture notes
Lecture notes will be distributed.

Literature

No mandatory prerequisites.

Microscopy Training TEM I - Introduction to TEM

The number of participants is limited. In case of overbooking, the course will be repeated once. All registrations will be recorded on the waiting list.

For PhD students, postdocs and others, a fee will be charged (http://www scopem.ethz.ch/education/MTP.html).

All applicants must additionally register on this form: (link will follow)

The selected applicants will be contacted and asked for confirmation a few weeks before the course date.

Abstract
The introductory course on Transmission Electron Microscopy (TEM) provides theoretical and hands-on learning for beginners who are interested in using TEM for their Master or PhD thesis. TEM sample preparation techniques are also discussed. During hands-on sessions at different TEM instruments, students will have the opportunity to examine their own samples if time allows.

Objective
Understanding of
1. the set-up and individual components of a TEM
2. the basics of electron optics and image formation
3. the basics of electron beam – sample interactions
4. the contrast mechanism
5. various sample preparation techniques

Learning how to
1. align and operate a TEM
2. acquire data using different operation modes of a TEM instrument, i.e. Bright-field and Dark-field imaging
3. record electron diffraction patterns and index diffraction patterns
4. interpret TEM data

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### Content

Lectures:
- basics of electron optics and the TEM instrument set-up
- TEM imaging modes and image contrast
- STEM operation mode
- Sample preparation techniques for hard and soft materials

Practicals:
- Demo, practical demonstration of a TEM: instrument components, alignment, etc.
- Hands-on training for students: sample loading, instrument alignment and data acquisition.
- Sample preparation for different types of materials
- Practical work with TEMs
- Demonstration of advanced Transmission Electron Microscopy techniques

### Literature


### Prerequisites / notice

No mandatory prerequisites. Please consider the prior attendance to EM Basic lectures (551-1618-00V; 227-0390-00L; 327-0703-00L) as suggested prerequisite.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>363-0541-00L</td>
<td>Systems Dynamics and Complexity</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>F. Schweitzer</td>
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### Abstract

Finding solutions: what is complexity, problem solving cycle.

### Objective

A successful participant of this course is able to:

- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics

### Content

Why are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical systems dynamics, nonlinear dynamics and macroeconomic modeling.

The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts.

These are provided as home work and two of these will be graded (see "Prerequisites").

### Lecture notes

Lecture notes will be distributed.

<table>
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<tr>
<th>Code</th>
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<tr>
<td>363-1065-00L</td>
<td>Design Thinking: Human-Centred Solutions to Real World Challenges</td>
<td>W</td>
<td>5</td>
<td>5G</td>
<td>S. Brusoni</td>
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</table>

**Does not take place this semester.**

The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Information and application: http://sparklabs.ch/

### Objective

During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:

1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes
13. Outlook

Literature
- Lecture material (slides).
  (It is not required to buy the book, as the library has it)

Prerequisites / notice
For non-CS/DS students only, BSc and MSc
Elementary knowledge of set theory and logic
Knowledge as well as basic experience with a programming language such as Pascal, C, C++, Java, Haskell, Python

Abstract

Applying two fundamental principles of thermodynamics (entropy maximization and Gibbs energy minimization), an analytical model is derived for a variety of biological phenomena at the molecular as well as cellular level, and critically compared with the corresponding experimental data in the literature.
Objective

Engineering uses the laws of physics to predict the behavior of a system. Biological systems are so diverse and complex prompting the question whether we can apply unifying concepts of theoretical physics coping with the multiplicity of life's mechanisms.

Objective of this course is to show that biological phenomena despite their variety can be analytically described using only two principles from statistical mechanics: maximization of the entropy and minimization of the Gibbs free energy.

Starting point of the course is the probability theory, which enables to derive step-by-step the two pillars thermodynamics from the perspective of statistical mechanics: the maximization of entropy according to the Boltzmann’s law as well as the minimization of the Gibbs free energy. Then, an assortment of biological phenomena at the molecular and cellular level (e.g. cytoskeletal polymerization, action potential, photosynthesis, gene regulation, morphogen patterning) will be examined at the light of these two principles with the aim to derive a quantitative expression describing their behavior. Each analytical model is finally validated by comparing it with the corresponding available experimental results.

By the end of the course, students will also learn to critically evaluate the concepts of making an assumption and making an approximation.

Content

• Basics of theory of probability
• Boltzmann's law
• Entropy maximization and Gibbs free energy minimization
• Ligand-receptor: two-state systems and the MWC model
• Random walks, diffusion, crowding
• Electrostatics for salty solutions
• Elasticity: fibers and membranes
• Molecular motors
• Action potential: Hodgkin-Huxley model
• Photosynthesis and vision
• Gene regulation
• Development: Turing patterns
• Sequences and evolution

Theory and corresponding exercises are merged together during the classes.

Lecture notes

No lecture notes because the two proposed textbooks are more than exhaustive!

An extra hour (Mon 17.00 o'clock - 18.00) will be proposed via zoom to solve together the exercises of the previous week.

!!!!! I am using OneNote. All lectures and exercises will be broadcast via ZOOM and correspondingly recorded (link in Moodle) !!!!!

Literature


Prerequisites / notice

Participants need a good command of
• differentiation and integration of a function with one or more variables (basics of Analysis),
• Newton's and Coulomb's laws (basics of Mechanics and Electrostatics).

No notions of vectors in 2D and 3D are beneficial.

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies not assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies

Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity assessed
Negotiation not assessed

Domain D - Personal Competencies

Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

701-1253-00L Analysis of Climate and Weather Data

Does not take place this semester.

Abstract

An introduction into methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of deterministic and probabilistic predictions, principal component analysis. Participants understand the theoretical concepts and purpose of methods, can apply them independently and know how to interpret results professionally.

Objective

Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.
The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Lecture notes
Documentation and supporting material:
- slides used during the lecture
- exercise sets and solutions
- R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

Literature
For complementary reading:

Prerequisites / notice
Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umweltwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

151-0209-00L Renewable Energy Technologies W 4 credits 3G A. Steinfeld, E. I. M. Casati
---
Objective
Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

Lecture notes
Lecture Notes containing copies of the presented slides.

Prerequisites / notice
Prerequisite: strong background on the fundamentals of engineering thermodynamics, equivalent to the material taught in the courses Thermodynamics I, II, and III of D-MAVT.

701-1257-00L European Climate Change W 3 credits 2G C. Schär, J. Rajczak, S. C. Scherrer
---
Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
- observational datasets, observation and detection of climate change;
- underlying physical processes and feedbacks;
- numerical and statistical approaches;
- currently available projections.

Objective
At the end of this course, participants should:
- understand the key physical processes shaping climate change in Europe;
- know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
- be familiar with relevant observational and modeling data sets;
- be able to tackle simple climate change questions using available data sets.

Content
Contents:
- global context
- observational data sets, analysis of climate trends and climate variability in Europe
- global and regional climate modeling
- statistical downscaling
- key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects
- projections of European and Alpine climate change

Lecture notes
Slides and lecture notes will be made available at http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice
Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

363-0537-00L Resource and Environmental Economics W 3 credits 2G L. Bretschger
---
Abstract
Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

Objective
A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.
### Content

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course proceeds to advanced topics according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

### Literature


### 227-0147-10L VLSI 3: Full-Custom Digital Circuit Design

**Abstract**

This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals are to learn how to design digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.

**Objective**

At the end of this course you will
- understand how the main building blocks of state-of-the-art digital integrated circuits are designed
- be able to design and optimize digital integrated circuits on the schematic, layout, and gate levels
- be able to use standard industry software (Cadence Virtuoso) for drawing, simulating, and characterizing digital circuits
- understand the performance trade-offs between speed, area, and power consumption

**Content**

The third VLSI course begins with the basics of metal-oxide-semiconductor (MOS) field-effect transistors (FETs) and moves up the stack towards logic gates and increasingly complex digital circuit structures. The topics of this course include:

- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

### Prerequisites / notice

VLSI3 can be taken in parallel with "VLSI1: HDL based design for FPGAs" and is designed to complement the topics of this course. Basic analog circuit knowledge is required.

### Proseminars and Semester Papers

To organise a semester project take contact with one of the instructors.

Not all lecturers are directly eligible in myStudies if "Professors" is the required type of lecturers. In such cases please take contact with the Study Administration (www.phys.ethz.ch/studies/study-administration.html).

#### Number Title Type ECTS Hours Lecturers

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0210-MSL</td>
<td>Proseminar Theoretical Physics ■</td>
<td>W</td>
<td>8</td>
<td>4S</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td>The number of participants is limited.</td>
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<tr>
<td>Abstract</td>
<td>A guided self-study of original papers and of advanced textbooks in theoretical physics. Within the general topic, determined each semester, participants give a presentation on a particular subject and deliver a written report.</td>
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<tr>
<td>402-0217-MSL</td>
<td>Semester Project in Theoretical Physics ■</td>
<td>W</td>
<td>8</td>
<td>15A</td>
<td>Supervisors</td>
</tr>
<tr>
<td></td>
<td>This course unit is an alternative if no suitable &quot;Proseminar Theoretical Physics&quot; is available of if the proseminar is already overbooked.</td>
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<tr>
<td>402-0215-MSL</td>
<td>Experimental Semester Project in Physics ■</td>
<td>W</td>
<td>8</td>
<td>15A</td>
<td>Supervisors</td>
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<td></td>
<td>The aim of the project is to give the student experience in working in a research environment, carrying out physics experiments, analysing and interpreting the resulting data.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Die Leistungskontrolle erfolgt aufgrund eines oder mehrerer schriftlicher Berichte bzw. einer schriftlichen Arbeit. Ein Vortrag über die gewonnenen Ergebnisse ist ein obligatorischer Bestandteil der Leistungskontrolle.</td>
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<tr>
<td>402-0740-00L</td>
<td>Experimental Foundations of Particle Physics</td>
<td>W</td>
<td>8</td>
<td>3S</td>
<td>M. Backhaus, M. Donegá</td>
</tr>
<tr>
<td></td>
<td>The Standard Model of particle physics is a monumental achievement of human ingenuity. While typically approached from the theoretical side, in this proseminar we will collect the experimental evidence upon which the Standard Model has been built.</td>
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<tr>
<td>Objective</td>
<td>This course integrates knowledge of all detector components (tracking, calorimetry, trigger) in discussing the experiments as a whole. It is meant to be complementary to the &quot;Experimental Methods&quot; course 402-0725-00L which introduces different detector technologies. It also augments the particle physics master curriculum and is meant to be followed in parallel to PPP I (402-0891-00L) or PPP II (402-0702-00L).</td>
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</table>

Content

The course will not follow the historical trajectory of experimental particle physics. It will instead try to give a modern view of the results of the experiments and show where they fit in the theoretical construction.

The students will read the original papers collected in the seminal text by Cahn and Goldhaber. The theory will be distilled to the very basics using the textbook by Bettini.

Introductory material:
- Review of basic relativistic kinematics (Lorentz transformations, invariant mass, etc.)
- Passage of particles through matter: Bethe Bloch dE/dx, bremsstrahlung, photon interactions, electromagnetic showers, hadronic showers, Cherenkov radiation, Transition Radiation

Experimental papers discussed in the course:
- Deep Inelastic scattering
- J/psi and tau discovery
- strong interaction: gluons and jets (anti-k_t jet clustering)
- parity violation, neutrino observation, neutrino helicity
- neutral current, W/Z discovery
- number of neutrino families, muon pair production asymmetry, W+W- production
- top/bottom discoveries
- Higgs discovery and properties
- CP violation in the kaon system
- Neutrino oscillations

The course is completed with in class detector demonstrations:
- cloud chamber
- cosmics rays with plastic scintillators
- cerenkov light in water
- silicon detectors

Literature

Cahn, Goldhaber "Experimental Foundations of Particle Physics" (2nd edition), Cambridge University Press
Bettini, "Introduction to Elementary Particle Physics" Cambridge University Press

Prerequisites / notice

Recommended: Phenomenology of Particle Physics I (or II) (in parallel)

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Communication
- Critical Thinking
- Integrity and Work Ethics
- Self-direction and Self-management

402-0717-MSL Particle Physics at CERN

Abstract

During the semester break participating students stay for 4 weeks at CERN and perform experimental work relevant to our particle physics projects. Dates to be agreed upon.

Objective

Students learn, by doing, the needed skills to perform a small particle physics experiment: setup, problem solving, data taking, analysis, interpretation and presentation in a written report of publication quality.

Content

Detailed information in: https://ethteilchenpraktikumn.web.cern.ch/

Language of instruction: English or German

402-0719-MSL Particle Physics at PSI (Paul Scherrer Institute)

Abstract

During semester breaks 6-12 students stay for 3 weeks at PSI and participate in a hands-on course on experimental particle physics. A small real experiment is performed in common, including apparatus design, construction, running and data analysis. The course includes some lectures, but the focus lies on the practical aspects of experimenting.

Objective

Students learn all the different steps it takes to perform a complete particle physics experiment in a small team. They acquire skills to do this themselves in the team, including design, construction, data taking and data analysis.

402-0340-MSL Medical Physics

Abstract

In agreement with the lecturers a semester paper in the context of the topics discussed in the lectures can be written.

GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-PHYS.

Master's Thesis

Number Title Type ECTS Hours Lecturers

402-2000-00L Scientific Works in Physics O 0 credits C. Eichler

Target audience:
Master students who cannot document to have received an adequate training in working scientifically.

Directive


Abstract

Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective

Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

402-0900-30L Master's Thesis O 30 credits 57D Supervisors
Only students who fulfil the following criteria are allowed to begin with their master's thesis:

a. successful completion of the bachelor programme;
b. fulfilling of any additional requirements necessary to gain admission to the master programme.
c. have acquired at least 8 credits in the category Proseminars and Semester Papers.

Further information:
http://www.phys.ethz.ch/phys/education/master/msc-theses

Abstract
The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Seminars, Colloquia, and Additional Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>402-0101-00L</td>
<td>The Zurich Physics Colloquium</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>S. Huber, A. Refregier, University lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0800-00L</td>
<td>The Zurich Theoretical Physics Colloquium</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>J. Renes, University lecturers</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>Objective</td>
<td>The Zurich Theoretical Physics Colloquium is jointly organized by the University of Zurich and ETH Zurich. Its mission is to bring both students and faculty with diverse interests in theoretical physics together. Leading experts explain the basic questions in their field of research and communicate the fascination for their work.</td>
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<tr>
<td>401-5330-00L</td>
<td>Talks in Mathematical Physics</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>P. E. Y. Bousseau, A. Cattaneo, G. Felder, M. Gaberdiel, G. M. Graf, T. H. Willwacher</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0501-00L</td>
<td>Solid State Physics</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>A. Zheludev, C. Degen, K. Ensslin, D. Pescia, M. Sigrist, A. Wallraff</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0551-00L</td>
<td>Laser Seminar</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>T. Esslinger, J. Faist, J. Home, U. Keller, F. Merkt, H. J. Wörner</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0600-00L</td>
<td>Nuclear and Particle Physics with Applications</td>
<td>E-</td>
<td>0 credits</td>
<td>2S</td>
<td>A. Rubbia, G. Dissertori, K. S. Kirch, R. Wallny</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0893-00L</td>
<td>Particle Physics Seminar</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>T. K. Gehrmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Occasionally, talks may be delivered in German.</td>
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<tr>
<td>402-0700-00L</td>
<td>Seminar in Elementary Particle Physics</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>M. Spira, University lecturers</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>Objective</td>
<td>Special Students UZH must book the modul PHY463 directly at UZH.</td>
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<tr>
<td>402-0746-00L</td>
<td>Seminar: Particle and Astrophysics (Aktuelles aus der Teilchen- und Astrophysik)</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>University lecturers</td>
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<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>Content</td>
<td>In Seminarvorträgen werden aktuelle Fragestellungen aus der Teilchenphysik vom theoretischen und experimentellen Standpunkt aus diskutiert. Besonders wichtig erscheint uns der Bezug zu den eigenen Forschungsmöglichkeiten am PSI, CERN und DESY.</td>
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<tr>
<td>402-0300-00L</td>
<td>IPA Colloquium</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>A. Biland, A. Refregier, H. M. Schmid, further lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0396-00L</td>
<td>Recent Research Highlights in Astrophysics (University of Zurich)</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>University lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>Objective</td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: AST006</td>
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<tr>
<td>Content</td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html">https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html</a></td>
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<tr>
<td>402-0530-00L</td>
<td>Mesoscopic Systems</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>T. M. Ihn</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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<tr>
<td>402-0620-00L</td>
<td>Current Topics in Accelerator Mass Spectrometry and Its Applicatons</td>
<td>E-</td>
<td>0 credits</td>
<td>1S</td>
<td>M. Christl, S. Willett</td>
</tr>
<tr>
<td>Abstract</td>
<td>The seminar is aimed at all students who, during their studies, are confronted with age determination methods based on long-living radionuclides found in nature. Basic methodology, the latest developments, and special examples from a wide range of applications will be discussed.</td>
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</tbody>
</table>
**227-0980-00L**  
**Seminar on Biomedical Magnetic Resonance**  
**Abstract** Current developments and problems of magnetic resonance imaging (MRI)  
**Objective** Getting insight into advanced topics in magnetic resonance imaging  
**Instructors** K. P. Prüssmann, S. Kozerke, M. Weiger Senften

**227-1043-00L**  
**Neuroinformatics - Colloquia (University of Zurich)**  
No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.  
UZH Module Code: INI701  
**Abstract** The colloquium in Neuroinformatics is a series of lectures given by invited experts. The lecture topics reflect the current themes in neurobiology and neuromorphic engineering that are relevant for our Institute.  
**Objective** The goal of these talks is to provide insight into recent research results. The talks are not meant for the general public, but really aimed at specialists in the field.  
**Content** The topics depend heavily on the invited speakers, and thus change from week to week.  
All topics concern neural computation and their implementation in biological or artificial systems.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Code</th>
<th>Credits</th>
<th>Weekly</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basics of Computing Environments for Scientists</td>
<td>402-0010-00L</td>
<td>0</td>
<td>Z</td>
<td>C. D. Herzog, C. Becker, S. Müller</td>
</tr>
</tbody>
</table>

**651-1581-00L**  
**Seminar in Glaciology**  
**Abstract** Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.  
**Objective** In-depth knowledge of selected topics research in Glaciology. Introduction to different types of scientific presentation. Improve ability of the discussion of scientific topics.  
**Content** Selected topics of scientific research in Glaciology  
**Lecture notes** Copies/pdf of scientific papers will be distributed during the course  
**Prerequisites / notice** Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:  
- 651-3561-00L Kryosphäre  
- 101-0289-00L Applied Glaciology  
- 651-4101-00L Physics of Glaciers

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<tr>
<td>Basics of Computing Environments for Scientists</td>
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<td>0</td>
<td>Z</td>
<td>C. D. Herzog, C. Becker, S. Müller</td>
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</tbody>
</table>

**402-0010-00L**  
**Basics of Computing Environments for Scientists**  
**Abstract** Introduction provides a good understanding of how IT works at D-PHYS and presents an overview of the IT services and their providers. It is recommended for everyone joining the department.  
**Objective** The remainder is structured into individual modules which can be attended separately. They give practical insights into everyday research-related IT challenges.  
The "Linux Basics" modules offer an introduction to the Linux landscape and show how to work on the shell by using command line tools. The first part provides a basic understanding of Linux systems and their components. It introduces commands essential to working with local and remote machines. The second part focuses on more advanced tools and workflows and provides guidelines to scripting, automation and customization.  
The "Python Ecosystem" modules present various aspects on the ecosystem around Python, without covering the programming language itself. The first part focuses on getting ready to run code. It discusses the management of Python interpreters, packages and virtual environments. The second part presents tools for writing code. From development environments (IDE, Jupyter), over code formatters and linters, to skimming selected concepts (string formatting, regular expressions).  
The "System Aspects module" deals with the hardware-related side of scientific computing. To get the best performance out of your scientific code, you have to be aware of the underlying hardware and adapt to it.  
Use the dedicated web page https://www.lehrbetrieb.ethz.ch/laborpraktika to register. Enrolled students are eligible for an attestation of attendance after visiting at least 3 out of the 5 modules. Refer to https://compenv.phys.ethz.ch for the detailed contents.  
**Content**  
IT at D-PHYS (IT service providers and IT services at D-PHYS)  
**Modules:**  
- Linux Basics I (system components, basic shell usage)  
- Linux Basics II (advanced tools, scripting)  
- Python Ecosystem I (interpreters, packages, virtual environments)  
- Python Ecosystem II (development environments, formatter and linter, string formatting, regexp)  
- System Aspects (how the hardware affects your scientific code and vice versa)
The courses below are only available for MSc students with additional admission requirements.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>406-0204-AAL</td>
<td>Electrodynamics</td>
<td>E-</td>
<td>7</td>
<td>15R</td>
<td>C. Anastasiou</td>
</tr>
<tr>
<td>401-2673-AAL</td>
<td>Numerical Methods for CSE</td>
<td>E-</td>
<td>9</td>
<td>19R</td>
<td>R. Hiptmair</td>
</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract


Objective

Develop a physical understanding for static and dynamic phenomena related to (moving) charged objects and understand the structure of the classical field theory of electrodynamics (transverse versus longitudinal physics, invariances (Lorentz-, gauge-)). Appreciate the interrelation between electric, magnetic, and optical phenomena and the influence of media. Understand a set of classic electrodynamical phenomena and develop the ability to solve simple problems independently. Apply previously learned mathematical concepts (vector analysis, complete systems of functions, Green's functions, co- and contravariant coordinates, etc.). Prepare for quantum mechanics (eigenvalue problems, wave guides and cavities).

Content

Classical field theory of electrodynamics: Derivation and discussion of Maxwell equations, starting from the static limit (electrostatics, magnetostatics, boundary value problems) in the vacuum and in media and subsequent generalization to the full dynamical case (Faraday's law, Ampere/Maxwell law; potentials and gauge invariance). Wave equation and solutions in full space, half-space (Snell's law), waveguides, cavities, generation of electromagnetic radiation, scattering and diffraction of light (optics). Application to various specific examples. Discussion of the structure of Maxwell's equations, Lorentz invariance, relativity theory and covariance, Lagrangian formulation. Dynamics of relativistic particles in the presence of fields and their radiation properties (synchrotron).

Literature

J.D. Jackson, Classical Electrodynamics
W.K.H Panovsky and M. Phillips, Classical electricity and magnetism
A. Sommerfeld, Elektrodynamik, Optik (Vorlesungen über theoretische Physik)
M. Born and E. Wolf, Principles of optics
R. Feynman, R. Leighton, and M. Sands, The Feynman Lectures of Physics, Vol II

M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002

Prequisites / notice

Solid knowledge about fundamental concepts and techniques from linear algebra & calculus as taught in the first year of science and engineering curricula.

The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves.

Dr Suitable for doctorate | W | Eligible for credits
O Compulsory | E- | Recommended, not eligible for credits
W+ Eligible for credits and recommended | Z | Courses outside the curriculum
### Key for Hours

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>ECTS</th>
<th>Remarks</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Students in the Joint Degree Master's Programme "Quantitative Finance" must book University of Zurich modules directly at the University of Zurich. Those modules are not listed here.

### Core Courses

#### Economic Theory for Finance

For possible (additional) course offerings see www.msfinance.ch

#### Mathematical Methods for Finance

For possible additional course offerings see www.msfinance.ch

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4 credits</td>
<td>3V+2U</td>
<td>B. Acciaio</td>
</tr>
</tbody>
</table>

**Abstract**

First introduction to main modelling ideas and mathematical tools from mathematical finance

**Objective**

This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

**Content**

Topics to be covered include

- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

**Lecture notes**

Lecture notes will be sold at the beginning of the course.

**Literature**

Lecture notes will be sold at the beginning of the course. Additional (background) references are given there.

**Prerequisites / notice**

Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitslehre".)

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

### Elective Courses

#### Economic Theory for Finance

For possible additional course offerings see www.msfinance.ch

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-4633-00L</td>
<td>Data Analytics in Organisations and Business</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>I. Flückiger</td>
</tr>
</tbody>
</table>

**Abstract**

On the end-to-end data analytics process in organizations & businesses and how to transform data into insights for fact-based decisions. Presentation of the process from the beginning with framing the business problem to presenting the results and making decisions using data analytics. For each topic, case studies from the financial service, healthcare, and retail sectors will be given.

**Objective**

This course aims to give the students an understanding of the data analytics process in the business world, with a particular focus on the skills and techniques used besides the technical skills. The student will become familiar with the "business language," current problems, and thinking in organizations and business and tools used.

**Content**

- Framing the Business Problem
- Framing the Analytics Problem
- Data Methodology
- Model Building
- Deployment
- Model Lifecycle

**Lecture notes**

The lecture's presentation slides will be provided.

**Prerequisites / notice**

Prerequisites: Basic statistics and probability theory and regression

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>363-1081-00L</td>
<td>Asset Liability Management and Treasury Risks</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>P. Mangold, M. Eichhorn</td>
</tr>
</tbody>
</table>

**Abstract**

Asset Liability Management (ALM) is key to the financial success of any corporation. The goal is to develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and related profits and losses, including identification and mitigation of undue risks taken. This course is geared towards preparing students to apply these concepts in practical settings.

**Objective**

The main learning objectives of this course are:

- develop a comprehensive understanding of the nature of corporate balance sheet and off-balance sheet positions and their respective contribution to profits and losses
- measure and assess exposures to risk factors such as interest and FX rates, equity and commodity prices, as well as liquidity events
- trading and hedging to mitigate undue risks incurred
The course is organized around a series of case studies. We will first discuss and develop an understanding of the fundamentals on different aspects of the management and risk management of the balance sheet. Using real life case studies each concept will then be directly applied and tested. In-class discussions, presentations and one written assignment are used to facilitate active and interactive learning in a stimulating environment. During the case studies students will frequently work in small groups. Therefore, the number of participants is limited to 40.

The course focuses on the application of finance concepts to the financial management of corporations and is geared towards preparing students to apply these concepts in practical settings. Executives of all sectors are expected to have a sound understanding of the content covered. As such, the course is not exclusively targeted at students who are considering a career in the financial services sector. It also recommended for students who want to work in the finance, treasury or risk area of corporates. It is also suitable for students who want to work for a consultancy firm.

No single textbook covers the course, below we list some useful references. Further materials will be made available to students prior to the lectures.


Participants should have a basic understanding of financial management, gained, for example, from prior undergraduate economics, business, or accounting studies.

## Mathematical Methods for Finance

*For possible additional course offerings see www.msfinance.ch*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3925-00L</td>
<td>Non-Life Insurance: Mathematics and Statistics</td>
<td>W</td>
<td>8 credits</td>
<td>4V+1U</td>
<td>M. V. Wüthrich</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture aims at providing a basis in non-life insurance mathematics which forms a core subject of actuarial science. It discusses collective risk modeling, individual claim size modeling, approximations for compound distributions, ruin theory, premium calculation principles, tariffication with generalized linear models and neural networks, credibility theory, claims reserving and solvency.

**Objective**
The student is familiar with the basics in non-life insurance mathematics and statistics. This includes the basic mathematical models for insurance liability modeling, pricing concepts, stochastic claims reserving models and ruin and solvency considerations.

**Content**
The following topics are treated:
- Collective Risk Modeling
- Individual Claim Size Modeling
- Approximations for Compound Distributions
- Ruin Theory in Discrete Time
- Premium Calculation Principles
- Tariffication
- Generalized Linear Models and Neural Networks
- Bayesian Models and Credibility Theory
- Claims Reserving
- Solvency Considerations

**Lecture notes**
M.V. Wüthrich, Non-Life Insurance: Mathematics & Statistics

**Literature**
M.V. Wüthrich, M. Merz. Statistical Foundations of Actuarial Learning and its Applications

**Prerequisites / notice**
This course will be held in English and counts towards the diploma of "Aktuar SAV". For the latter, see details under www.actuaries.ch.

Prerequisites: knowledge of probability theory, statistics and applied stochastic processes.

**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories assessed
- Domain B - Method-specific Competencies: Techniques and Technologies assessed

**401-4889-00L Mathematical Finance**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mathematical Finance</td>
<td>W</td>
<td>11 credits</td>
<td>4V+2U</td>
<td>D. Possamaï</td>
</tr>
</tbody>
</table>

**Abstract**
Advanced course on mathematical finance:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- additional topics

**Objective**
This is an advanced course on mathematical finance for students with a good background in probability theory and stochastic calculus (for continuous processes)

**Content**
Topics include:
- semimartingales and general stochastic integration
- absence of arbitrage and martingale measures
- fundamental theorem of asset pricing
- option pricing and hedging
- hedging duality
- optimal investment problems
- and probably others

**Lecture notes**
The course is based on different parts from different books as well as on original research literature.

Notes:
- Lecture notes will not be available.
- (will be updated later)
Prerequisites / notice

Prerequisites are the standard courses
- Probability Theory (for which lecture notes are available)
- Brownian Motion and Stochastic Calculus (for which lecture notes are available)

Those students who already attended "Introduction to Mathematical Finance" will have an advantage in terms of ideas and concepts.

This course is the second of a sequence of two courses on mathematical finance. The first course "Introduction to Mathematical Finance" (MF I), 401-3888-00, focuses on models in finite discrete time. It is advisable that the course MF I is taken prior to the present course, MF II.

For an overview of courses offered in the area of mathematical finance, see https://www.math.ethz.ch/imsf/education/education-in-stochastic-finance/overview-of-courses.html.

**401-4657-00L Numerical Analysis of Stochastic Ordinary Differential Equations**

<table>
<thead>
<tr>
<th>W</th>
<th>6 credits</th>
<th>3V+1U</th>
<th>A. Stein</th>
</tr>
</thead>
</table>

**Abstract**

Course on numerical approximations of stochastic ordinary differential equations driven by Wiener processes. These equations have several applications, for example in financial option valuation. This course also contains an introduction to random number generation and Monte Carlo methods for random variables.

**Objective**

The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

**Content**

Generation of random numbers
Monte Carlo methods for the numerical integration of random variables
Stochastic processes and Brownian motion
Stochastic ordinary differential equations (SODEs)
Numerical approximations of SODEs
Applications to computational finance: Option valuation

**Lecture notes**

There will be English, typed lecture notes for registered participants in the course.

**Literature**


**Prerequisites / notice**

Prerequisites:
Mandatory: Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.

a) mandatory courses:
Elementary Probability, Probability Theory I.

b) recommended courses:
Stochastic Processes.


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**401-3929-00L Financial Risk Management in Social and Pension Insurance**

<table>
<thead>
<tr>
<th>W</th>
<th>4 credits</th>
<th>2V</th>
<th>P. Blum</th>
</tr>
</thead>
</table>

**Abstract**

Investment returns are an important source of funding for social and pension insurance, and financial risk is an important threat to stability. We study short-term and long-term financial risk and its interplay with other risk factors, and we develop methods for the measurement and management of financial risk and return in an asset/liability context with the goal of assuring sustainable funding.

**Objective**

Understand the basic asset-liability framework: essential principles and properties of social and pension insurance; cash flow matching, duration matching, valuation portfolio and loose coupling; the notion of financial risk; long-term vs. short-term risk; coherent measures of risk.

Understand the conditions for sustainable funding: derivation of required returns; interplay between return levels, contribution levels and other parameters; influence of guaranteed benefits.

Understand the notion of risk-taking capability: capital process as a random walk; measures of long-term risk and relation to capital; short-term solvency vs. long-term stability; effect of embedded options and guarantees; interplay between required return and risk-taking capability.

Be able to study empirical properties of financial assets: the Normal hypothesis and the deviations from it; statistical tools for investigating relevant risk and return properties of financial assets; time aggregation properties; be able to conduct analysis of real data for the most important asset classes.

Understand and be able to address essential problems in asset / liability management, e.g. optimal risk / return positioning, optimal discount rate, target value for funding ratio or turnaround issues.

Understand and be able to carry out portfolio construction: the concept of diversification; limitations to diversification; correlation breakdown; incorporation of constraints; sensitivities and shortcomings of optimized portfolios.

Understand and interpret the asset-liability interplay: the optimized portfolio in the asset-liability framework; short-term risk vs. long-term risk; the influence of constraints; feasible and non-feasible solutions; practical considerations.

Have an overall view: see the big picture of what asset returns can and cannot contribute to social security; be aware of the most relevant outcomes; know the role of the actuary in the financial risk management process.
For pension insurance and other forms of social insurance, investment returns are an important source of funding. In order to earn these returns, substantial financial risks must be taken, and these risks represent an important threat to financial stability, in the long term and in the short term.

Risk and return of financial assets cannot be separated from one another and, hence, asset management and risk management cannot be separated either. Managing financial risk in social and pension insurance is, therefore, the task of reconciling the contradictory dimensions of

1. Required return for a sustainable funding of the institution,
2. Risk-taking capability of the institution,
3. Returns available from financial assets in the market,
4. Risks incurred by investing in these assets.

This task must be accomplished under a number of constraints. Financial risk management in social insurance also means reconciling the long time horizon of the promised insurance benefits with the short time horizon of financial markets and financial risk.

It is not the goal of this lecture to provide the students with any cookbook recipes that can readily be applied without further reflection. The goal is rather to enable the students to develop their own understanding of the problems and possible solutions associated with the management of financial risks in social and pension insurance.

To this end, a rigorous intellectual framework will be developed and a powerful set of mathematical tools from the fields of actuarial mathematics and quantitative risk management will be applied. When analyzing the properties of financial assets, an empirical viewpoint will be taken using statistical tools and considering real-world data.

This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and models for extreme events such as natural or man-made catastrophes. The lecture covers reinsurance contracts, experience and exposure pricing, natural catastrophe modelling, solvency regulation, and insurance linked securities transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.

Topics covered include:

- Reinsurance Contracts and Markets: Different forms of reinsurance, their mathematical representation, history of reinsurance, and lines of business.
- Experience Pricing: Modelling of low frequency high severity losses based on historical data, and analytical tools to describe and understand these models
- Exposure Pricing: Loss modelling based on exposure or risk profile information, for both property and casualty risks
- Natural Catastrophe Modelling: History, relevance, structure, and analytical tools used to model natural catastrophes in an insurance context
- Solvency Regulation: Regulatory capital requirements in relation to risks, effects of reinsurance thereon, and differences between the Swiss Solvency Test and Solvency 2
- Insurance linked securities: Alternative risk transfer techniques such as catastrophe bonds

Lecture notes
Extensive handouts will be provided. Moreover, practical examples and data sets in Excel and R will be made available.

Prerequisites / notice
Solid base knowledge of probability and statistics is indispensable. Specialized concepts from financial and insurance mathematics as well as quantitative risk management will be introduced in the lecture as needed, but some prior knowledge in some of these areas would be an advantage.

This course counts towards the diploma of "Aktuar SAV".

The exams ONLY take place during the official ETH examination period.

<table>
<thead>
<tr>
<th>401-3922-00L</th>
<th>Life Insurance Mathematics</th>
<th>W</th>
<th>4 credits</th>
<th>2V</th>
<th>M. Koller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>The classical life insurance model is presented together with the important insurance types (insurance on one and two lives, term and endowment insurance and disability). Besides that the most important terms such as mathematical reserves are introduced and calculated. The profit and loss account and the balance sheet of a life insurance company is explained and illustrated.</td>
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<td>Objective</td>
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<table>
<thead>
<tr>
<th>401-3928-00L</th>
<th>Reinsurance Analytics</th>
<th>W</th>
<th>4 credits</th>
<th>2V</th>
<th>P. Antal, P. Arbenz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>This course provides an introduction to reinsurance from an actuarial perspective. The objective is to understand the fundamentals of risk transfer through reinsurance and models for extreme events such as natural or man-made catastrophes. The lecture covers reinsurance contracts, experience and exposure pricing, natural catastrophe modelling, solvency regulation, and insurance linked securities transfer through reinsurance and the mathematical approaches associated with low frequency high severity events such as natural or man-made catastrophes.</td>
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<tr>
<td>Lecture notes</td>
<td>An excerpt of last year's lecture notes is available here: <a href="https://sites.google.com/site/philipparbenz/reinsuranceanalytics">https://sites.google.com/site/philipparbenz/reinsuranceanalytics</a></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basic knowledge in statistics, probability theory, and actuarial techniques</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies</td>
<td>Concepts and Theories</td>
<td>assessed</td>
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<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
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<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>Project Management</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
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<td>Customer Orientation</td>
<td>not assessed</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td></td>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<td></td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
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<td>Self-direction and Self-management</td>
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 ► Master's Thesis

see www.oec.uzh.ch/studies/general/theses/oec_en.html

### Quantitative Finance Master - Key for Type

<table>
<thead>
<tr>
<th>Key for Type</th>
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<td>O</td>
<td>Compulsory</td>
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<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
<tr>
<td>E</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
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### Key for Hours

<table>
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<th>Description</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<tr>
<td>G</td>
<td>lecture with exercise</td>
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<tr>
<td>U</td>
<td>exercise</td>
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<tr>
<td>S</td>
<td>seminar</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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<tr>
<td>P</td>
<td>practical/laboratory course</td>
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<tr>
<td>A</td>
<td>independent project</td>
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<tr>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

ECTS

European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Quantum Engineering Master

▸ Core Courses

A minimum of 24 credits must be obtained from core courses during the MSc QE. course selection is subject to the tutor's agreement.

▸▸ Quantum Technology Lab

This core course is a prerequisite for participation in the QuanTech Labs of the second and third semester.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>227-1831-10L</td>
<td>Case Studies: Applications of Quantum Technology</td>
<td>W+</td>
<td>3</td>
<td>6G</td>
<td>G. Raino</td>
</tr>
</tbody>
</table>

Abstract:
In this course students will be exposed to different topics of quantum engineering and develop ideas for possible projects. Based on presentations by ETH labs participating in the MSc QE program and with the assistance of a mentor students will work in groups to develop concrete plans for a quantum experiment.

Objective:
Acquire a broad overview of quantum engineering activities at ETH and develop own ideas about future quantum engineering projects.

▸▸ Engineering Core Courses

These core courses target students with a physics background and all those who need additional engineering foundations.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
</tbody>
</table>

Abstract:
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Objective:
Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.

Content:

Literature:

Prerequisites / notice
Prerequisites: Signal and Systems Theory II.

MATLAB is used for system analysis and simulation.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>227-0116-00L</td>
<td>VLSI 1: HDL based design for FPGAs</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>F. K. Gürkaynak, L. Benini</td>
</tr>
</tbody>
</table>

Abstract:
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective:
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content:
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and abstraction phases.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog.
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature

Prerequisites / notice
Prerequisites: Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

227-0166-00L Analog Integrated Circuits W 6 credits 2V+2U T. Jang

Abstract
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies. Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems. The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

Content
Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc; Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesizers; switched capacitors. The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

Literature

227-0301-00L Optical Communication Fundamentals W 6 credits 2V+1U+1P J. Leuthold

Abstract
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is discussed. The lecture covers the fundamentals of all important optical and optoelectronic components in a fiber communication system. This includes the transmitter, the fiber channel and the receiver with the electronic digital signal processing elements.

Content
* Chapter 1: Introduction: Analog/Digital conversion, The communication channel, Shannon channel capacity, Capacity requirements.
  * Chapter 4: The Receiver: Photodiodes, Receiver noise, Detector schemes (direct detection, coherent detection), Bit-error ratios and error estimations.
  * Chapter 5: Digital Signal Processing Techniques: Digital signal processing in a coherent receiver, Error detection techniques, Error correction coding.
  * Chapter 6: Pulse Shaping and Multiplexing Techniques: WDM/FDM, TDM, OFDM, Nyquist Multiplexing, OCDMA.
  * Chapter 7: Optical Amplifiers : Semiconductor Optical Amplifiers, Erbium Doped Fiber Amplifiers, Raman Amplifiers.

Lecture notes
Lecture notes are handed out.

Literature

Prerequisites / notice

227-0417-00L Information Theory I W 6 credits 4G A. Lapidoth

Abstract
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective
The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Content
The entropy rate of a source, Typical sequences, the asymptotic equi-partition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature
T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Physics Core Courses
These core courses target students with an engineering background and all those who need additional physics foundations.

Number Title Type ECTS Hours Lecturers
402-0205-00L Quantum Mechanics I W 10 credits 3V+2U M. Gaberdiel

Abstract

Objective
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator). Ability to solve simple problems.

Content
The beginnings of quantum theory with Planck, Einstein and Bohr; Wave mechanics; Simple examples; The formalism of quantum mechanics (states and observables, Hilbert spaces and operators, the measurement process); Heisenberg uncertainty relation; Harmonic oscillator; Symmetries (in particular rotations); Hydrogen atom; Angular momentum addition; Quantum mechanics and classical physics (EPR paradoxon and Bell's inequality); Perturbation theory.

Lecture notes
Auf Moodle, in deutscher Sprache

Literature
G. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L. I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics
Quantum Physics for Non-Physicists

W 6 credits 3V+2U  L. Pacheco Cañamero B. del Río

Abstract
This is an introduction to the physics of quantum mechanics, aimed primarily at students with little to no background in physics. We start from the basic postulates and follow an information-theoretical approach to study the behaviour of quantum systems, from a single spin to entangled particles in space and the hydrogen atom.

Objective
This course teaches the basics of quantum physics, and complements courses in quantum computation and information theory. Students are equipped with tools to tackle complex quantum mechanical problems and foundational questions. The course covers approximately the same content as QM1, but from an information-driven perspective.

Content
1. Quantum formalism, from qubits to particles in space
2. Time and dynamics for quantum systems
3. Problems in 1D
4. Uncertainty and open systems
5. Spin
6. Problems in 3D
7. Non-locality and foundational aspects of quantum theory

Lecture notes
Lecture notes will be distributed through the semester.

Literature
Quantum Processes Systems, and Information, by Benjamin Schumacher and Michael Westmoreland, available at https://www.cambridge.org/core/books/quantum-processes-systems-and-information/4E459E64E1EE7121CA2321435FAECC8A

Prerequisites / notice
This course is aimed at non-physicists, and in particular at students with a background in computer science, mathematics or engineering. Basic linear algebra and calculus knowledge is required (equivalent to first-year courses). Physics knowledge is not required. Physicists and students from a different background than outlined above are welcome at their own risk.

Note that while we follow an information-theoretical approach, this is not a course on quantum information theory or quantum computing. It therefore complements those courses offered at ETH in both semesters.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; ionic crystals; quantum aspects of solids; magnetic properties of solids; superconductors; semiconductors; transport properties; magnetism, superconductivity.

**Objective**
Introduction to Solid State Physics.

**Content**
The course provides an introduction to solid state physics, covering several topics that are later discussed in more detail in other more specialized lectures. The central topics are: solids and their lattice structures; ionic crystals; quantum aspects of solids; magnetic properties of solids; superconductors; semiconductors; transport properties; magnetism, superconductivity.

**Lecture notes**
The script will be available on moodle.

**Literature**
Ibach & Lüth, Festkörperphysik
C. Kittel, Festkörperphysik
Ashcroft & Mermin, Festkörperphysik
W. Känzig, Kondensierte Materie

**Prerequisites / notice**
Voraussetzungen: Physik I, II, III wünschenswert

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<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>402-0442-00L</td>
<td>Quantum Optics</td>
<td>W</td>
<td>10</td>
<td>3V+2U</td>
<td>T. Esslinger</td>
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<tr>
<td>402-0861-00L</td>
<td>Statistical Physics</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>M. Sigrist</td>
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<tr>
<td>402-0461-00L</td>
<td>Quantum Information Theory</td>
<td>W</td>
<td>8</td>
<td>3V+1U</td>
<td>P. Kammerlander</td>
</tr>
</tbody>
</table>

**Abstract**
This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics covered include the quantum nature of light, semi-classical and quantum mechanical description of light-matter interaction, laser manipulation of atoms and ions, optomechanics and quantum computation.

**Objective**
The course aims to provide the knowledge necessary for pursuing research in the field of Quantum Optics. Fundamental concepts and techniques of Quantum Optics will be linked to modern experimental research. During the course the students should acquire the capability to understand currently published research in the field.

**Content**
This course gives an introduction to the fundamental concepts of Quantum Optics and will highlight state-of-the-art developments in this rapidly evolving discipline. The topics that are covered include:

- coherence properties of light
- quantum nature of light: statistics and non-classical states of light
- light matter interaction: density matrix formalism and Bloch equations
- quantum description of light matter interaction: the Jaynes-Cummings model, photon blockade
- laser manipulation of atoms and ions: laser cooling and trapping, atom interferometry,
- further topics: Rydberg atoms, optomechanics, quantum computing, complex quantum systems.

**Lecture notes**
Selected book chapters will be distributed.

**Literature**
Text-books:
G. Gryenberg, A. Aspect and C. Fabre, Introduction to Quantum Optics
R. Loudon, The Quantum Theory of Light
Atomic Physics, Christopher J. Foot
Advances in Atomic Physics, Claude Cohen-Tannoudji and David Guéry-Odelin
C. Cohen-Tannoudji et al., Atom-Photon-Interactions
M. Scully and M.S. Zubairy, Quantum Optics
Y. Yamamoto and A. Imamoglu, Mesoscopic Quantum Optics

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**Abstract**
This course covers the concepts of classical and quantum statistical physics. Several techniques such as second quantization formalism for fermions, bosons, photons and phonons as well as mean field theory and self-consistent field approximation. These are used to discuss phase transitions, critical phenomena and superfluidity.

**Objective**
This lecture gives an introduction in the basic concepts and applications of statistical physics for the general use in physics and, in particular, as a preparation for the theoretical solid state physics education.

**Content**
Kinetic approach to statistical physics: H-theorem, detailed balance and equilibrium conditions.
Classical statistical physics: microcanonical ensembles, canonical ensembles and grandcanonical ensembles, applications to simple systems.
Quantum statistical physics: density matrix, ensembles, Fermi gas, Bose gas (Bose-Einstein condensation), photons and phonons.
Identical quantum particles: many body wave functions, second quantization formalism, equation of motion, correlation functions, selected applications, e.g. Bose-Einstein condensate and coherent state, phonons in elastic media and melting.
One-dimensional interacting systems.
Phase transitions: mean field approach to Ising model, Gaussian transformation, Ginzburg-Landau theory (Ginzburg criterion), self-consistent field approach, critical phenomena, Peierls' arguments on long-range order.

**Lecture notes**
Lecture notes available in English.

**Literature**
No specific book is used for the course. Relevant literature will be given in the course.

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**Abstract**
The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

**Objective**
By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

**Content**
Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties.
Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

**Lecture notes**
Distributed via moodle.

**Literature**
Nielsen and Chuang, Quantum Information and Computation
Preskill, Lecture Notes on Quantum Computation
Wilde, Quantum Information Theory
Watrous, The Theory of Quantum Information

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**Electives**
This is a selection of courses particularly suitable for the MSc QE. In agreement with the tutor, students may choose other courses from the ETH course catalogue.

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Discrete-Time and Statistical Signal Processing  W  6 credits  4G  H.-A. Loeliger

Abstract
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications: discrete-time linear filters, inverse filters and equalization, DFT, discrete-time stochastic processes, elements of detection theory and estimation theory, LMMSE estimation and LMMSE filtering, LMS algorithm, Viterbi algorithm.

Objective
The course introduces some fundamental topics of digital signal processing with a bias towards applications in communications. The two main themes are linearity and probability. In the first part of the course, we deepen our understanding of discrete-time linear filters. In the second part of the course, we review the basics of probability theory and discrete-time stochastic processes. We then discuss some basic concepts of detection theory and estimation theory, as well as some practical methods including LMMSE estimation and LMMSE filtering, the LMS algorithm, and the Viterbi algorithm. A recurring theme throughout the course is the stable and robust "inversion" of a linear filter.

Content
1. Discrete-time linear systems and filters: state-space realizations, $z$-transform and spectrum, decimation and interpolation, digital filter design, stable realizations and robust inversion.
2. The discrete Fourier transform and its use for digital filtering:
   - Probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.
3. The statistical perspective: probability, random variables, discrete-time stochastic processes; detection and estimation: MAP, ML, Bayesian MMSE, LMMSE; Wiener filter, LMS adaptive filter, Viterbi algorithm.

Lecture notes
Lecture Notes

Solid State Electronics and Optics  W  6 credits  4G  N. Yazdani, V. Wood

Abstract
"Solid State Electronics" is an introductory condensed matter physics course covering crystal structure, electron models, classification of metals, semiconductors, and insulators, band structure engineering, thermal and electronic transport in solids, magnetoresistance, and optical properties of solids.

Objective
Understand the fundamental physics behind the mechanical, thermal, electric, magnetic, and optical properties of materials.

Prerequisites / notice
Recommended background: Undergraduate physics, mathematics, semiconductor devices

Analog-to-Digital Converters  W  6 credits  2V+2U

Abstract
Does not take place this semester.

This course provides a thorough treatment of integrated data conversion systems from system level specifications and trade-offs, over architecture choice down to circuit implementation. Data conversion systems are substantial sub-parts of many electronic systems, e.g. the audio conversion system of a home-cinema systems or the base-band front-end of a wireless modem. Data conversion systems usually determine the performance of the overall system in terms of dynamic range and linearity. The student will learn to understand the basic principles behind data conversion and be introduced to the different methods and circuit architectures to implement such a conversion. The conversion methods such as successive approximation or algorithmic conversion are explained with their principle of operation accompanied with the appropriate mathematical calculations, including the effects of non-idealties in some cases. After successful completion of the course the student should understand the concept of an ideal ADC, know all major converter architectures, their principle of operation and what governs their performance.

Content
- Introduction: information representation and communication; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.
- Dual-slope & successive approximation register (SAR) converters: dual slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array.
- Algorithmic & pipelined A/D converters: algorithmic conversion principle; sample & hold stage; pipe-lined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealties, error correction.
- Performance metrics and non-linearity: ideal ADC; offset; gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.
- Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.
- Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.
- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-order delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.

Lecture notes
Slides are available online under https://lis.students.ee.ethz.ch/lectures/analog-to-digital-converters/

Literature
- M. Gustavsson et. al., CMOS Data Converters for Communications, Springer, 2010

Prerequisites / notice
It is highly recommended to attend the course " Analog Integrated Circuits " of Prof. T. Jang as a preparation for this course.

Semiconductor Devices: Physical Bases and Simulation  W  4 credits  3G  A. Schenk, C. I. Roman

Abstract
The course addresses the physical principles of modern semiconductor devices and the foundations of their modeling and numerical simulation. Necessary basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided. Computer simulations of the most important devices and of interesting physical effects support the lectures.

Objective
The course aims at the understanding of the principle physics of modern semiconductor devices, of the foundations in the physical modeling of transport and its numerical simulation. During the course also basic knowledge on quantum-mechanics, semiconductor physics and device physics is provided.

Content
The main topics are: transport models for semiconductor devices (quantum transport, Boltzmann equation, drift-diffusion model, hydrodynamic model), physical characterization of silicon (intrinsic properties, scattering processes), mobility of cold and hot carriers, recombination (Shockley-Read-Hall statistics, Auger recombination), impact ionization, metal-semiconductor contact, metal-insulator-semiconductor structure, and heterojunctions. The exercises are focussed on the theory and the basic understanding of the operation of special devices, as single-electron transistor, resonant tunneling diode, pn-diode, bipolar transistor, MOSFET, and laser. Numerical simulations of such devices are performed with an advanced simulation package (Sentaurus-Synopsys). This enables to understand the physical effects by means of computer experiments.

Lecture notes
The script (in book style) can be downloaded from: https://lis.students.ee.ethz.ch/lectures/

Literature
The script (in book style) is sufficient. Further reading will be recommended in the lecture.

Prerequisites / notice

Analog Integrated Circuits  W  6 credits  2V+2U  T. Jang
This course provides a foundation in analog integrated circuit design based on bipolar and CMOS technologies.

### Objective
Integrated circuits are responsible for much of the progress in electronics in the last 50 years, particularly the revolutions in the Information and Communications Technologies we witnessed in recent years. Analog integrated circuits play a crucial part in the highly integrated systems that power the popular electronic devices we use daily. Understanding their design is beneficial to both future designers and users of such systems.

### Content
The basic elements, design issues and techniques for analog integrated circuits will be taught in this course.

- Review of bipolar and MOS devices and their small-signal equivalent circuit models; Building blocks in analog circuits such as current sources, active load, current mirrors, supply independent biasing etc.
- Amplifiers: differential amplifiers, cascode amplifier, high gain structures, output stages, gain bandwidth product of op-amps; stability; comparators; second-order effects in analog circuits such as mismatch, noise and offset; data converters; frequency synthesize; switched capacitors.

The exercise sessions aim to reinforce the lecture material by well guided step-by-step design tasks. The circuit simulator SPECTRE is used to facilitate the tasks. There is also an experimental session on op-amp measurements.

### Literature

### Lecture notes
Handouts of presented slides. No script but an accompanying textbook is recommended.

### Prerequisites
Sufficient mathematical maturity, in particular in linear algebra, analysis.
The course is an introduction to some basic topics in signal processing and machine learning.

A solid base of Analysis I & II as well as of Linear Algebra is really helpful.

IMPORTANT: Wed 22.9, 29.9, and 22.12 are lectures (NOT exercises!). Please, look at the details in moodle!

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
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<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
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<td>Techniques and Technologies</td>
<td>Decision-making</td>
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<td>Creative Thinking</td>
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<td>Media and Digital Technologies</td>
<td>Customer Orientation</td>
<td>Critical Thinking</td>
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<td>Problem-solving</td>
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<td>Self-presentation and Social Influence</td>
<td>Self-awareness and Self-reflection</td>
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</table>

227-0427-00L **Signal Analysis, Models, and Machine Learning**

**W** 6 credits 4G H.-A. Loeliger

*Does not take place this semester.*

*This course was replaced by “Introduction to Estimation and Machine Learning” and “Advanced Signal Analysis, Modeling, and Machine Learning”.*

**Abstract**

I. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.

II. Learning linear and nonlinear functions and filters: neural networks, kernel methods.

III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.

**Objective**

The course is an introduction to some basic topics in signal processing and machine learning.

**Content**


Lecture notes

Lecture notes.

Prerequisites / notice

- local bachelor's course “Discrete-Time and Statistical Signal Processing” (5. Sem.)
- others: solid basics in linear algebra and probability theory

227-0468-00L **Analog Signal Processing and Filtering**

**W** 6 credits 2V+2U H. Schmid

*Suitable for Master Students as well as Doctoral Students.*

**Abstract**

This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers.

**Objective**

This lecture provides a wide overview over analog filters (continuous-time and discrete-time), signal-processing systems, and sigma-delta conversion, and gives examples with sensor interfaces and class-D audio drivers. All systems and circuits are treated using a signal-flow view. The lecture is suitable for both analog and digital designers. The way the exam is done allows for the different interests of the two groups.

**Content**

The learning goal is that the students can apply signal-flow graphs and can understand the signal flow in such circuits and systems (including non-ideal effects) well enough to gain an understanding of further circuits and systems by themselves.

At the beginning, signal-flow graphs in general and driving-point signal-flow graphs in particular are introduced. We will use them during the whole term to analyze circuits on a system level (analog continuous-time, analog discrete-time, mixed-signal and digital) and understand how signals propagate through them. The theory and CMOS implementation of active Filters is then discussed in detail using the example of Gm-C filters and active-RC filters. The ideal and nonideal behaviour of opamps, current conveyors, and inductor simulators follows. The link to the practical design of circuits and systems is done with an overview over different quality measures and figures of merit used in scientific literature and datasheets. Finally, an introduction to discrete-time and mixed-domain filters and circuits is given, including sensor read-out amplifiers, correlated double sampling, and chopping, and an introduction to sigma-delta A/D and D/A conversion on a system level.

This lecture does not go down to the details of transistor implementations. The lecture “227-0166-00L Analog Integrated Circuits” complements This lecture very well in that respect.

**Lecture notes**

The base for these lectures are lecture notes and two or three published scientific papers. From these papers we will together develop the technical content.

Details: https://people.ee.ethz.ch/~haschmid/asfwiki/

The graph methods are also supported with teaching videos: https://tube.switch.ch/channels/d206c96c?order=episodes , and a Python-based open-source tool to manipulate graphs is available on https://github.com/hanspi42/signalflowgrapher

Some material is protected by password; students from ETHZ who are interested can write to haschmid@ethz.ch to ask for the password even if they do not attend the lecture.
Knowledge of the Laplace transform and z transform and their interpretation (transfer functions, poles and zeros, bode diagrams, stability criteria) ... and of the main properties of linear systems is necessary.

Objectives

1. Electrodynamics
2. Physics 1,2
3. Introduction to quantum mechanics

Abstract

The lecture starts with summarizing the relevant fundamentals of the treatment of noisy signals. We familiarize ourselves with the concept of measurement imprecision in light-based measurement systems. To this end, we consider the process of photodetection and discuss the statistical fluctuations arising from the quantization of the electromagnetic field into photons. We exemplify our insights at hand of concrete examples, such as homodyne and heterodyne photodetection. Furthermore, we focus on the process of measurement backaction, the inevitable result of the interaction of the probe with the system under investigation. The course emphasizes the connection between the taught concepts and current state-of-the-art research carried out in the field of optomechanics.

Literature

 Mostly the original articles, other useful reading can be found in:

- E. Rosencher and B. Vinter, Optoelectronics, Cambridge Univ. Press
- G. Bastard, Wave mechanics applied to semiconductor heterostructures, Halsted press

Prerequisites / notice

Requirements: A basic knowledge of solid-state physics and of quantum electronics.

Electromagnetic Precision Measurements and Opto- Mechanics

402-0465-58L Intersubband Optoelectronics

Does not take place this semester.

Abstract

Intersubband transitions in quantum wells are transitions between states created by quantum confinement in ultra-thin layers of semiconductors. Because of its inherent taylorability, this system can be seen as the "ultimate quantum designer's material".

Objective

The goal of this lecture is to explore both the rich physics as well as the application of these system for sources and detectors. In fact, devices based on intersubband transitions are now unlocking large area of the electromagnetic spectrum.

Content

The lecture will treat the following chapters:
- Introduction: intersubband optoelectronics as an example of quantum engineering
- Technological aspects
- Electronic states in semiconductor quantum wells
- Intersubband absorption and scattering processes
- Mid-IR and THz ISB Detectors
- Mid-infrared and THz photonics: waveguides, resonators, metamaterials
- Quantum Cascade lasers:
  - Mid-IR CCLs
  - THz QCLs (direct and non-linear generation)
- further electronic confinement: interlevel Qdot transitions and magnetic field effects
- Strong light-matter coupling in Mid-IR and THz range

Lecture notes

The reference book for the lecture is "Quantum Cascade Lasers" by Jerome Faist, published by Oxford University Press.

Prerequisites / notice

Requirements: Basic knowledge of solid-state physics and of quantum electronics.

Nonlinear Optics

227-0655-00L

Does not take place this semester.

Abstract

Nonlinear Optics deals with the interaction of light with material, the response of material to light and the mathematical framework to describe the phenomena. As an example we will cover fundamental phenomena such as the refractive index, the electro-optic effect, second harmonic generation, four-wave mixing or soliton propagation and others.

Objective

The important nonlinear optical phenomena are understood and can be classified. The effects can be described mathematical by means of the susceptibility.
Nano-Optics
Lecture notes are distributed. For students enrolled in the course, additional information, lecture notes and exercises can be found on moodle (https://moodle-app2.let.ethz.ch/).


3V+2U+4A
W
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Introduction to Dynamic Programming and Optimal Control.

Nano-Optics is the study of light-matter interaction at the sub-wavelength scale. It is an flourishing field of fundamental and applied Computer Science II.

No lecture notes, but slides will be made available on the course webpage.

W
Understanding concepts of light localization and light-matter interactions on the sub-wavelength scale.

Computer Science II
No lecture notes, but slides will be made available on the course webpage.

W
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics experience for solving assignments.

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

Nano-Optics
Lecture notes are distributed. For students enrolled in the course, additional information, lecture notes and exercises can be found on moodle (https://moodle-app2.let.ethz.ch/).


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PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
The course provides the foundations for the design and analysis of algorithms. Classical problems ranging from sorting up to problems on graphs are used to discuss common data structures, algorithms and algorithm design paradigms.

The course also comprises an introduction to parallel and concurrent programming.

### Objective
An understanding of the analysis and design of fundamental and common algorithms and data structures. Knowledge regarding chances, problems and limits of parallel and concurrent programming.

### Content
Data structures and algorithms: mathematical tools for the analysis of algorithms (asymptotic function growth, recurrence equations, recurrence trees), informal proofs of algorithm correctness (invariants and code transformation), design paradigms for the development of algorithms (induction, divide-and-conquer, backtracking and dynamic programming), classical algorithmic problems (searching, selection and sorting), data structures for different purposes (linked lists, hash tables, balanced search trees, heaps, union-find), further tools for runtime analysis (generating functions, amortized analysis). The relationship and tight coupling between algorithms and data structures is illustrated with graph algorithms (traversals, topological sort, closure, shortest paths, minimum spanning trees).

Parallel programming: structure of parallel architectures (multicore, vectorization, pipelining) concepts of parallel programming (Amdahl's and Gustavson's laws, task/data parallelism, scheduling), problems of concurrency (data races, bad interleavings, memory reordering), process synchronisation and communication in a shared memory system (mutual exclusion, semaphores, monitors, condition variables).

The concepts are underpinned with examples of concurrent and parallel programs and with parallel algorithms, implemented in C++.

In general, the concepts provided in the course are motivated and illustrated with practically relevant algorithms and applications.

Exercises are carried out in Code-Expert, an online IDE and exercise management system.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
</table>

#### 402-0257-00L Advanced Solid State Physics

**W** 10 credits 3V+2U

**K. Povarov**

This course is an extension of the introductory course on solid state physics.

The purpose of this course is to learn to navigate the complex collective quantum phases, excitations and phase transitions that are the dominant theme in modern solid state physics. The emphasis is on the main concepts and on specific experimental examples, both classic ones and those from recent research.

### Objective
The goal is to study how novel phenomena emerge in the solid state.

- Today's challenges and opportunities in Solid State Physics

- Phase transitions and critical phenomena
  - Main concepts: coherence length, symmetry, order parameter, correlation functions, generalized susceptibility
  - Bragg-Williams mean field theory
  - Landau theory of phase transitions
  - Fluctuations in Landau theory
  - Critical exponents: significance, measurement, inequalities, equalities
  - Scaling and hyperscaling
  - Universality
  - Critical dynamics
  - Quantum phase transitions and quantum criticality

- Fermi surface instabilities
  - The concept of the Landau Fermi liquid in metals
  - Kohn anomalies
  - Charge density waves
  - Metallic ferromagnets and half-metals
  - Spin density waves

- Magnetism of insulators
  - Magnetic interactions in solids and the spin Hamiltonian
  - Magnetic structures and phase transitions
  - Spin waves
  - Quantum magnetism

- Electronic correlations in solids
  - Mott insulating state
  - Phases of the Hubbard model
  - Layered cuprates (non-superconducting properties)

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#### 402-0317-00L Semiconductor Materials: Fundamentals and Fabrication

**W** 6 credits

**2V+1U**

**S. Schön, W. Wegscheider**

This course gives an introduction into the fundamentals of semiconductor materials. The main focus is on state-of-the-art fabrication and characterization methods. The course will be continued in the spring term with a focus on applications.

### Abstract
Basic knowledge of semiconductor physics and technology. Application of this knowledge for state-of-the-art semiconductor device processing.
The lecture covers the following topics:

1. Fundamentals of Solid State Physics
2. Semiconductor materials
3. Band structures
4. Carrier statistics in intrinsic and doped semiconductors
5. p-n junctions
6. Low-dimensional structures
7. Bulk Material growth of Semiconductors
8. Czochralski method
9. Floating zone method
10. High pressure synthesis
11. Semiconductor Epitaxy
12. Fundamentals of Epitaxy
13. Molecular Beam Epitaxy (MBE)
14. Metal-Organic Chemical Vapor Deposition (MOCVD)
15. Liquid Phase Epitaxy (LPE)
16. In situ characterization
17. Pressure and temperature
18. Reflectometry
19. Ellipsometry and RAS
20. LEED, AES, XPS
21. STM, AFM

The "compulsory performance element" of this lecture is a short presentation of a research paper complementing the lecture topics. Several topics and corresponding papers will be offered on the moodle page of this lecture.

402-0402-00L Ultrafast Laser Physics

| W | 10 credits | 3V+2U | L. P. Gallmann, S. Johnson, U. Keller |

The lecture covers the following topics:

a) Linear pulse propagation: mathematical description of pulses and their propagation in linear optical systems, effect of dispersion on ultrashort pulses, concepts of pulse carrier and envelope, time-bandwidth product

b) Dispersion compensation: technologies for controlling dispersion, pulse shaping, measurement of dispersion

c) Nonlinear pulse propagation: intensity-dependent refractive index (Kerr effect), self-phase modulation, nonlinear pulse compression, self-focusing, filamentation, nonlinear Schrödinger equation, solitons, non-instantaneous nonlinear effects (Raman/Brillouin), self-steepening, saturable gain and absorption

d) Second-order nonlinearities with ultrashort pulses: phase-matching with short pulses and real beams, quasi-phase matching, second-harmonic and sum-frequency generation, parametric amplification and generation

e) Relaxation oscillations: dynamical behavior of rate equations after perturbation

f) Q-switching: active Q-switching and its theory based on rate equations, active Q-switching technologies, passive Q-switching and theory

g) Active modelocking: introduction to modelocking, frequency comb versus axial modes, theory for various regimes of laser operation, Haus master equation formalism

h) Passive modelocking: slow, fast and ideally fast saturable absorbers, semiconductor saturable absorber mirror (SESAM), designs of and materials for SESAMs, modelocking with slow absorber and dynamic gain saturation, modelocking with ideally fast saturable absorber, Kerr-lens modelocking, soliton modelocking, Q-switching instabilities in modelocked lasers, inverse saturable absorption

i) Pulse duration measurements: rf cables and electronics, fast photodiodes, linear system theory for microwave test systems, intensity and interferometric autocorrelations and their limitations, frequency-resolved optical gating, spectral phase interferometry for direct electric-field reconstruction and more

j) Noise: microwave spectrum analyzer as laser diagnostics, amplitude noise and timing jitter of ultrafast lasers, lock-in detection

k) Ultrafast measurements: pump-probe scheme, transient absorption/differential transmission spectroscopy, four-wave mixing, optical gating and more

l) Frequency combs and carrier-envelope offset phase: measurement and stabilization of carrier-envelope offset phase (CEP), time and frequency domain applications of CEP-stabilized sources

m) High-harmonic generation and attosecond science: non-perturbative nonlinear optics / strong-field phenomena, high-harmonic generation (HHG), phase-matching in HHG, attosecond pulse generation, attosecond technology: detectors and diagnostics, attosecond metrology (streaking, RABBITT, transient absorption, attoclock), example experiments

n) Ultrafast THz science: generation and detection, physics in THz domain, weak-field and strong-field applications

o) Brief introduction to other hot topics: relativistic and ultra-high intensity ultrafast science, ultrafast electron sources, free-electron lasers, etc.
Superconducting Circuits provide a versatile experimental platform to explore the most intriguing quantum-physical phenomena and
atomic paramagnetism and diamagnetism, itinerant and local-moment interatomic coupling, magnetic order at finite temperature, spin
precession, approach to equilibrium through thermal and quantum dynamics, dipolar interaction in solids.

- Apply concepts of quantum-mechanics to estimate the strength of atomic magnetic moments and their interactions
- Identify the mechanisms from which exchange interaction originates in solids (itinerant and local-moment magnetism)
- Evaluate the consequences of the interplay between competing interactions and thermal energy
- Apply general concepts of statistical physics to determine the origin of bistability in realistic magnets
- Discriminate the dynamic responses of a magnet to different external stimuli

Quantum Gases are the most precisely controlled many-body systems in physics. This provides a unique interface between theory and
experiment, which allows addressing fundamental concepts and long-standing questions. This course lays the foundation for the
understanding of current research in this vibrant field.

- Discriminate the dynamic responses of a magnet to different external stimuli
- Apply general concepts of statistical physics to determine the origin of bistability in realistic magnets
- Identify the mechanisms from which exchange interaction originates in solids (itinerant and local-moment magnetism)
- Evaluate the consequences of the interplay between competing interactions and thermal energy
- Apply concepts of quantum-mechanics to estimate the strength of atomic magnetic moments and their interactions

Does not take place this semester.

Quantum Science with Superconducting Circuits

Abstract
Superconducting Circuits provide a versatile experimental platform to explore the most intriguing quantum-physical phenomena and constitute one of the prime contenders to build quantum computers. Students will get a thorough introduction to the underlying physical concepts, the experimental setting, and the state-of-the-art of quantum computing in this emerging research field.

Objective
Based on today’s most advanced solid state platform for quantum control, the students will learn how to engineer quantum coherent devices and how to use them to process quantum information. The students will acquire both analytical and numerical methods to model the properties and phenomena observed in these systems. The course is positioned at the intersection between quantum physics and engineering.

Content

Prerequisites / notice
All students and researchers with a general interest in quantum information science, quantum optics, and quantum engineering are welcome to this course. Basic knowledge of quantum physics is a plus, but not a strict requirement for the successful participation in this course.

Optical Properties of Semiconductors

Abstract
This course presents a comprehensive discussion of optical processes in semiconductors.

Objective
The rich physics of the optical properties of semiconductors, as well as the advanced processing available on these material, enabled numerous applications (lasers, LEDs and solar cells) as well as the realization of new physical concepts. Systems that will be covered include quantum dots, exciton-polaritons, quantum Hall fluids and graphene-like materials.

Content
Electronic states in III-V materials and quantum structures, optical transitions, excitons and polaritons, novel two dimensional semiconductors, spin-orbit interaction and magneto-optics.

Prerequisites / notice
Prerequisites: Quantum Mechanics I, Introduction to Solid State Physics

Experimental and Theoretical Aspects of Quantum Gases

Abstract
Quantum Gases are the most precisely controlled many-body systems in physics. This provides a unique interface between theory and experiment, which allows addressing fundamental concepts and long-standing questions. This course lays the foundation for the understanding of current research in this vibrant field.

Objective
The lecture conveys a basic understanding for the current research on quantum gases. Emphasis will be put on the connection between theory and experimental observation. It will enable students to read and understand publications in this field.

Content
Bose and Fermi gases

- Ultracold collisions
- The Bose-condensed state
- Elementary excitations
- Vortices
- Superfluidity
- Interference and Correlations
- Optical lattices

Literature

Application of Quantum Computers

Abstract
Quantum computing systems are not yet large enough for practial application. This course represents an introduction to the field of quantum computing.

Objective
- Understand the basic principles of quantum computing
- Be able to use a quantum computer as a tool for solving problems
- Understand the basics of quantum algorithms
- Understand the basics of quantum error correction
- Understand the basics of quantum cryptography

Content
- Introduction to quantum mechanics
- Introduction to quantum computing
- Quantum algorithms
- Quantum error correction
- Quantum cryptography

Prerequisites / notice
Masters level quantum optics knowledge
The lecture "Introduction to Magnetism" is a regular course of the Physics MSc program and aims at letting students familiarize themselves with the basic principles of quantum and statistical physics that determine the behavior of real magnets. Understanding why only few materials are magnetic at finite temperature will be the leitmotiv of the course. We will see that defining in a formal way what "being magnetic" means is essential to address this question properly. Theoretical concepts will be applied to few selected nano-sized magnets, which will serve as clean reference systems.

At the end of this course students should have acquired the basic knowledge needed to develop a research project in the field of magnetism or to attend effectively more advanced courses on this topic.

Preliminary contents for the HS21:
- Magnetism in atoms (quantum-mechanical origin of atomic magnetic moments, intra-atomic exchange interaction)
- Magnetism in solids (mechanisms producing inter-atomic exchange interaction in solids, crystal field).
- Spin resonance and relaxation (Larmor precession, resonance phenomena, quantum tunneling, Bloch equation, superparamagnetism)
- Magnetic order at finite temperatures (Ising and Heisenberg models, low-dimensional magnetism)
- Dipolar interaction in solids (shape anisotropy, dipolar frustration, origin of magnetic domains)

The students will receive an extended lecture summary as well as numerous MATHEMATICA and Python scripts, including QuTiP notebooks. These tools will enable them to apply analytical and numerical methods to a wide range of systems beyond the duration of the course.
Prerequisites / notice The students should be familiar with wave mechanics as well as second quantization. Following the course requires a laptop with Python and MATHEMATICA installed.

### Semester Project

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<td>12</td>
<td>20A</td>
<td>Supervisors</td>
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<td>Registration in myStudies required!</td>
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<tr>
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<td>Supervisor must be a professor at D-ITET or D-PHYS, see <a href="http://master-qq.ee.ethz.ch/education/semester-project.html">http://master-qq.ee.ethz.ch/education/semester-project.html</a></td>
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</table>

Abstract Semester projects are designed to train the students for independent scientific work. A project uses the student's technical and social skills acquired during the master's program. The semester project comprises 280 hours of work and is supervised by a professor.

Prerequisites / notice Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

### Internship

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<th>Number</th>
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<tr>
<td>227-1873-00L</td>
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<td>Only for Quantum Engineering MSc.</td>
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Abstract The main objective of the 12-week internship is to expose bachelor's students to the industrial work environment. During this period, students have the opportunity to be involved in on-going projects at the host institution.

### Master's Thesis

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<tr>
<th>Number</th>
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<td>Admission only if ALL of the following apply:</td>
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<td>a) bachelor program successfully completed;</td>
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<td>b) acquired (if applicable) all credits from additional requirements for admission to master program;</td>
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<tr>
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<td>c) successfully completed the semester project.</td>
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Note: the conditions above are not applicable to incoming exchange students.

Registration in myStudies required!

Supervisor must be a professor at D-ITET or D-PHYS, see http://master-qq.ee.ethz.ch/education/master-project.html. 

Abstract The Master Program finishes with a 6-months Master Thesis which is directed by a Professor of the Department or a Professor of another Department who is associated with the D-ITET. Students gain the ability to conduct independent scientific research on a specific research problem.

Prerequisites / notice Supervisor must be a professor at D-ITET or associated, see https://www.ee.ethz.ch/studies/main-master/projects-and-master-thesis.html

### GESS Science in Perspective

**see Science in Perspective: Language Courses ETH/UZH**

**see Science in Perspective: Type A: Enhancement of Reflection Capability**

**Recommended Science in Perspective (Type B) for D-ITET**

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**Quantum Engineering Master - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctrate</th>
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<tbody>
<tr>
<td>E-</td>
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<tr>
<td>Dr</td>
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</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
<th>practical/laboratory course</th>
<th>independent project</th>
<th>diploma thesis</th>
<th>revision course / private study</th>
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</table>

**ECTS** European Credit Transfer and Accumulation System

■ Special students and auditors need special permission from the lecturers.
### Basic Courses

#### First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0241-00L</td>
<td>Analysis I</td>
<td>O</td>
<td>7 credits</td>
<td>5V+2U</td>
<td>M. Akveld</td>
</tr>
<tr>
<td>Abstract</td>
<td>Mathematical tools for the engineer</td>
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</tr>
<tr>
<td>Objective</td>
<td>Mathematics as a tool to solve engineering problems.</td>
<td></td>
<td></td>
<td></td>
<td>Mathematical formulation of technical and scientific problems.</td>
</tr>
<tr>
<td>Content</td>
<td>Complex numbers.</td>
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<tr>
<td></td>
<td>Calculus for functions of one variable with applications.</td>
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<tr>
<td>Lecture notes</td>
<td>Wird auf der Vorlesungshomepage zu Verfügung gestellt.</td>
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<tr>
<td></td>
<td>Tilo Arens et al., &quot;Mathematik&quot;, Springer; online verfügbar unter: <a href="http://link.springer.com/book/10.1007/978-3-642-44919-2/page/1">link</a></td>
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<td></td>
<td>Urs Stammbach, &quot;Analysis III&quot; (erhältlich im ETH Store); <a href="https://people.math.ethz.ch/~stammb/analysisskript.html">link</a></td>
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<tr>
<td>401-0141-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5 credits</td>
<td>3V+1U</td>
<td>M. Akka Ginosar</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Linear Algebra</td>
<td></td>
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<tr>
<td>Objective</td>
<td>Basic knowledge of linear algebra as a tool for solving engineering problems.</td>
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<tr>
<td></td>
<td>Understanding abstract mathematical formulation of technical and scientific problems. Together with Analysis we develop the basic mathematical knowledge for an engineer.</td>
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</tr>
<tr>
<td>Content</td>
<td>Introduction and linear systems of equations, matrices, quadratic matrices, determinants and traces, general vector spaces, linear mappings, bases, change of basis, diagonalization, eigenvalues and eigenvectors, orthogonal transformations, scalar-product, inner product spaces.</td>
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<tr>
<td>Lecture notes</td>
<td>Calculation with MATLAB will be introduced in the first exercise class.</td>
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<tr>
<td>Literature</td>
<td>The lecturer will provide course notes.</td>
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<tr>
<td></td>
<td>K. Nipp, D. Stoffer, Lineare Algebra, VdF Hochschulverlag ETH</td>
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<tr>
<td></td>
<td>G. Strang, Lineare Algebra, Springer</td>
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<tr>
<td>252-0845-00L</td>
<td>Computer Science I</td>
<td>O</td>
<td>5 credits</td>
<td>2V+2U</td>
<td>C. Cotrini Jimenez, R. Sasse</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the basic concepts of computer programming.</td>
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<tr>
<td>Objective</td>
<td>Basic understanding of programming concepts. Students will be able to write and read simple programs and to modify existing programs.</td>
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<tr>
<td>Content</td>
<td>Variablen, Typen, Kontrollanweisungen, Prozeduren und Funktionen, Scoping, Rekursion, dynamische Programmierung, vektorisierte Programmierung, Effizienz.</td>
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<tr>
<td></td>
<td>Als Lernsprache wird Java eingesetzt.</td>
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<tr>
<td>Literature</td>
<td>Sprechen Sie Java? Hanspeter Mössenböck dpunkt.verlag</td>
<td></td>
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</tr>
<tr>
<td>103-0313-00L</td>
<td>Spatial Planning and Landscape Development</td>
<td>O</td>
<td>5 credits</td>
<td>4G</td>
<td>A. Grêt-Regamey, K. Hollenstein, J. Van Wezemael</td>
</tr>
<tr>
<td>Abstract</td>
<td>The lecture introduces into the main-features of spatial planning. Attended will be the subjects planning as a national responsibility, instruments of spatial planning, techniques for problem solving in spatial planning and the Swiss concept for national planning. The lecture is complemented with in-depth topics and international examples.</td>
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<tr>
<td>Objective</td>
<td>Die Studierenden kennen die Grundzüge der Raumplanung, ihre wichtigen Instrumente und Problemlösungsverfahren. Sie können das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Übungsaufgaben umsetzen.</td>
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<td></td>
<td>- Grundzüge der Raumplanung und ihre wichtigsten Instrumente kennenlernen</td>
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<td></td>
<td>- Erarbeiten der Fähigkeit, räumliche Probleme zu erkennen und Problemlösungsverfahren auf diese anzuwenden</td>
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<td></td>
<td>- Planung und Landmanagement als interaktiven Prozess kennenlernen und anwenden</td>
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<td></td>
<td>- Verstehen der mit Fläche und Boden verbundenen Potentiale, Nutzungen und Prozesse</td>
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<td></td>
<td>- Das vermittelte theoretische Wissen direkt an konkreten, praxisorientierten Fallbeispielen umsetzen können</td>
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<tr>
<td>Literature</td>
<td>Die Vorlesung deckt die Grundlagen der (Schweizerischen) Raumplanung und Landschaftsentwicklung ab:</td>
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<tr>
<td></td>
<td>- Was ist Raumplanung (Begriffe)</td>
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<tr>
<td></td>
<td>- Prinzipien der Raumplanung</td>
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<td></td>
<td>- Die Raumplanung als staatliche Aufgabe - Raumordnungspolitik</td>
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<tr>
<td></td>
<td>- Instrumente der Raumplanung auf den Planungsebenen (u.a. Sachpläne und Konzepte, Richtplanung, Nutzungsplanung, Sondernutzungsplanung, Landumlegungsverfahren)</td>
<td></td>
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<tr>
<td></td>
<td>- Problemlösungsverfahren in der Raumplanung - systemtechnisches Vorgehen</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>- Das schweizerische Raumordnungskonzept</td>
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<tr>
<td></td>
<td>Der Schwerpunkt der Vorlesung liegt auf der Erläuterung der Raumplanung als Problemlösungsverfahren. Das dabei vermittelte theoretische Wissen wird direkt an einer konkreten, praxisorientierten Übungsaufgabe umgesetzt. Im Rahmen der Übung wird das Projektgebiet während einer Exkursion besucht.</td>
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Classification of partial differential equations

Analysis III

We will model and solve scientific problems with partial differential equations. Differential equations which are important in applications will be classified and solved. Elliptic, parabolic and hyperbolic differential equations will be treated. The following mathematical tools will be introduced: Laplace and Fourier transforms, Fourier series, separation of variables, methods of characteristics.

Learning to model scientific problems using partial differential equations and developing a good command of the mathematical methods that can be applied to them. Knowing the formulation of important problems in science and engineering with a view toward civil engineering (when possible). Understanding the properties of the different types of partial differential equations arising in science and in engineering.

Classification of partial differential equations

Study of the Heat equation general diffusion-parabolic problems using the following tools through Separation of variables as an introduction to Fourier Series.

Systematic treatment of the complex and real Fourier Series

Study of the wave equation and general hyperbolic problems using Fourier Series, D’Alembert solution and the method of characteristics.

Laplace transform and its uses to differential equations

Study of the Laplace equation and general elliptic problems using similar tools and generalizations of Fourier series.

Application of Laplace transform for beam theory will be discussed.

Time permitting, we will introduce the Fourier transform.
Lecture notes will be provided

large part of the material follow certain chapters of the following first two books quite closely.


The course material is taken from the following sources:

Stanley J. Farlow - Partial Differential Equations for Scientists and Engineers

G. Felder: Partielle Differenzialgleichungen.
https://people.math.ethz.ch/~felder/PDG/


Prerequisites / notice

Analysis I and II, insbesondere, gewöhnliche Differentialgleichungen.

<table>
<thead>
<tr>
<th>103-0233-10L</th>
<th>Fundamentals of GIS</th>
<th>O</th>
<th>6 credits</th>
<th>5G</th>
<th>W. Kuhn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Fundamentals of geographic information systems: spatial data modeling; metrics &amp; topology; vector, raster and network data; thematic data; spatial statistics; system architectures; data quality; spatial queries and analysis; geovisualisation; spatial databases; group project with GIS software</td>
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<tr>
<td>Objective</td>
<td>Knowing theoretical aspects of geographic information regarding data acquisition, representation, analysis and visualisation. Knowing the fundamentals of geoinformation technologies for the realization, application and operation of geographic information systems in engineering projects.</td>
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<tr>
<td>Content</td>
<td>Einführung GIS &amp; GIScience, Konzeptionelles Modell &amp; Datenschema, Vektorgeometrie &amp; Topologie, Rastergeometrie und -algebra, Netzwerke, Thematische Daten, Räumliche Statistik, Systemarchitekturen &amp; interoperabilität, Datenqualität, Unsicherheiten &amp; Metadaten, Räumliche Abfragen und Analysen, Präsentation raumbezogener Daten, Geodatenbanken</td>
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<tr>
<td>Lecture notes</td>
<td>Vorlesungspräsentationen werden digital zur Verfügung gestellt.</td>
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<table>
<thead>
<tr>
<th>103-0187-02L</th>
<th>Satellite Geodesy</th>
<th>O</th>
<th>4 credits</th>
<th>3G</th>
<th>M. Rothacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Sicherheit im Umgang mit Koordinaten-, Referenz- und Zeitsystemen, Grundlegendes Verständnis der geodätischen Weltraumverfahren und deren Stärken und Schwächen, Kenntnis der wichtigsten Prozesse, die für Änderungen in den drei Pfeilern der Space Geodesy (der Geometrie, der Rotation und dem Schwerfeld der Erde) verantwortlich sind, Erkennen der Anwendungsmöglichkeiten der Space Geodesy für interdisziplinäre Aufgaben (System Erde).</td>
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<table>
<thead>
<tr>
<th>102-0675-00L</th>
<th>Earth Observation</th>
<th>O</th>
<th>4 credits</th>
<th>3G</th>
<th>I. Hajnek, E. Baltasvias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.</td>
<td></td>
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<tr>
<td>Objective</td>
<td>The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation. Students should know at the end of the course: Basics of measurement principle, Fundamentals of image acquisition, Basics of the sensor-specific geometries, Sensor-specific determination of environmental parameters</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Die Lehrveranstaltung gibt einen Einblick in die heutige Erdbeobachtung mit den folgenden skizzierten Inhalten: Einführung in die Fernerkundung von Luft- und Weltraum gestützten Systemen, Einführung in das Elektromagnetische Spektrum, Optische Systeme (optisch und hyperspektoral), Einführung in Mikrowellen-Technik (aktiv und passiv), Einführung in atmosphärische Systeme (meteo und chemisch), Einführung in die Techniken und Methoden zur Bestimmung von Umweltparametern, Einführung in die Anwendungen zur Bestimmung von Umweltparametern in der Hydrologie, Glaziologie, Forst und Landwirtschaft, Geologie und Topographie</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>Folien zu jeden Vorlesungsblock werden zur Verfügung gestellt.</td>
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</tr>
<tr>
<td>Literature</td>
<td>Ausgewählte Literatur wird am Anfang der Vorlesung vorgestellt.</td>
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</tbody>
</table>


Abstract
This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

Objective
After successful completion of the course you will be able to:
- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

Content
Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.

Lecture notes
no script available

Literature

Prerequisites / notice
Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

Domain A - Subject-specific Competencies
- Concepts and Theories assessed

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Domain D - Personal Competencies
- Critical Thinking assessed
- Self-direction and Self-management assessed

851-0703-00L Introduction to Law O 2 credits 2V O. Streiff Gnöpff

Abstract
This class introduces students into basic features of the legal system. Fundamental issues of constitutional law, administrative law, private law and the law of the EU are covered.

Objective
Students are able to identify basic structures of the legal system. They understand selected topics of public and private law and are able to apply the fundamentals in more advanced law classes.

Content
Basic concepts of law, sources of law.
Private law: Contract law (particularly contract for work and services), tort law, property law.
Public law: Human rights, administrative law, procurement law, procedural law.
Insights into the law of the EU and into criminal law.

Lecture notes
Jaap Hage, Bram Akkermans (Eds.), Introduction to Law, Cham 2017 (Online Resource ETH Library)

Literature
Further documents will be available online (see https://moodle-app2.let.ethz.ch/course/view.php?id=15142).

Examination block 2

Number Title Type ECTS Hours Lecturers
402-0043-00L Physics I O 4 credits 3V+1U J. Home
Abstract
Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.

Objective
The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.

Content
Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids)
Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).

Lecture notes
The lecture follows the book "Physics" by Paul A. Tipler.

Literature
Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company

103-0253-01L Parameter Estimation O 4 credits 3G E. Brockmann
Objective
- Beherrschung der Grundlagen der Parameterschätzung
- Erlangung von Kalkülsicherheit
- Erkennen von Problemen, die mit Parameterschätzungsverfahren gelöst werden können
- Im Stande sein, relevante Problembesteiligungen auf die Parameterabschätzungsmodelle abzubilden
- Befähigt sein, mit Messunsicherheiten umzugehen und Resultate in Bezug auf ihre Qualität / Unsicherheiten zu beurteilen
- Interdisziplinäre Anwendungsmöglichkeiten der Parameterschätzung erkennen
This course provides an introduction to operations research methods in the fields of management science and economics. Requisite mathematical concepts are introduced with a practical, problem-solving perspective.

Quantitative models and methods of operations research and operations management offer decision support for complex problems. Mathematical optimization models are used to precisely formulate operational decision problems so that they can subsequently be analysed and optimized using suitable solution methods. A large number of quantitative real-world problems can be formulated and solved in this general framework. Applications of operations research comprise, for instance, decision problems in production planning, supply chain management, transportation networks, machine and workforce scheduling, blending of components, telecommunication network design, airline fleet assignment and revenue management.

This course offers an introduction to operations research, emphasizing basic methodologies and underlying mathematical structures. The following topics are covered in detail:

- Introduction to system modelling and operations research
- Linear models and the importance of linear programming
- Duality theory in linear programming and shadow prices
- Integer programming
- Dynamic optimization (under uncertainty) and applications in inventory management.

Lecture notes
A printed script will be made available.

Literature
Any standard textbook in Operations Research is a useful complement to the course.

Prerequisites / notice
Undergraduate calculus, linear algebra, probability and statistics are a prerequisite.

The world's growing population, changing demographics, and changing climate pose formidable challenges to humanity's ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth's growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:

- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.
The weekly lectures are structured as follows:

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. An introduction to the example that we will be working with through most of the course. The expectations of your efforts throughout the semester.

2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.

3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.

4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.

5. Analysis – 1/5 – The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, display, weighting, and expected value.

6. Analysis – 2/5 – The idea behind the supply and demand curves and revealed preference methods.

7. Analysis – 3/5 – The concept of equivalence, including the time value of money, interest, life times and terminal values.

8. Analysis – 4/5 – The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Marginal rates of return and internal rates of return.

9. Analysis – 5/5 – How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.

10. Evaluation of solutions – Regardless how sophisticated an analysis is, it requires that decision makers stand back and critically evaluate the results. This week we discuss the aspects of evaluating the results of an analysis.

11. Operations research – 1/4 – Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. This week we discuss linear programming and the simplex method.


13. Operations research – 3/4 – How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.

14. Operations research – 4/4 – How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches. The quantitative analyses requires the use of Excel. An introduction to Excel will be provided in one of the help sessions.

- The lecture materials consist of a script, the slides and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

This course has no prerequisites.

### Content

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories
  - Techniques and Technologies
- **Domain B - Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
- **Domain C - Social Competencies**
  - Communication
  - Cooperation and Teamwork
  - Customer Orientation
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity
  - Negotiation
- **Domain D - Personal Competencies**
  - Adaptability and Flexibility
  - Creative Thinking
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

### Literature

Appropriate literature in addition to the lecture materials will be handed out when required via Moodle.

### Prerequisites / notice

This course has no prerequisites.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
<th>Taught</th>
<th>Taught</th>
</tr>
</thead>
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<td></td>
<td>Techniques and Technologies</td>
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<td>B</td>
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<td></td>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
</tr>
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<td>Media and Digital Technologies</td>
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<td></td>
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<td>Problem-solving</td>
<td>assessed</td>
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<td></td>
<td></td>
<td>Project Management</td>
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</tr>
<tr>
<td>C</td>
<td>Social Competencies</td>
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<td>not assessed</td>
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<tr>
<td></td>
<td></td>
<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>D</td>
<td>Personal Competencies</td>
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<td></td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<td></td>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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</tbody>
</table>

### Abstract

The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established concepts and methods for project organization, planning, execution and evaluation are introduced and major challenges discussed. The course includes an introduction on specialized project management software as well as agile project management concepts.

### Objective

Projects are not only the base of work in modern enterprises but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project.

### Content

Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

### Lecture notes

- The lecture slides and other additional material will be available for download from Moodle a week before each class.

### Elective Blocks

#### Geodesy and Satellite Navigation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0139-00L</td>
<td>Geodetic Networks and Data Analysis</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>R. Hohensinn</td>
</tr>
</tbody>
</table>

The lecture provides knowledge about the planning, computation and analysis of geodetic networks, as well as the use of data analysis methods in geodesy in general. The necessary mathematical and statistical methods are presented and applied using examples from geodesy.

After completing this course, the participants should be equipped with the necessary tools to plan, analyze and evaluate geodetic networks as well as to evaluate and analyze geodetic data in general. For typical geodetic tasks the participants should be able to provide concepts of solutions as well as to do the necessary programming work.
Digitalisation and 3D Modelling

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>103-0115-01L</td>
<td>Geodetic Measuring Technology and Laserscanning</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Vollmer, A. Wieser N. Meyer</td>
</tr>
</tbody>
</table>

Objective
By the end of this course, the students are able to create digital 3D models of the real world covering areas with an extent up to several 100 m with accuracies in the mm- to cm-level range. They can select the appropriate geodetic instruments or terrestrial laser scanners, plan and carry out the required working steps, test the equipment before use, and describe the quality of the results. They know a broad spectrum of visualization options and can assess their respective suitability for various application cases.

Content
- Overview: 3D Modelling from planning of data acquisition to visualization of the results
- Modern geodetic instruments
- Atmospheric effects
- Measurement techniques for high accuracy
- Introduction to terrestrial laser scanning
- Test and calibration of measurement instruments
- Point cloud processing: preprocessing, registration & georeferencing
- 3D modelling and visualization of objects, VR/AR/MR

GIS and Cartography

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0717-00L</td>
<td>Geoinformation Technologies and Analysis</td>
<td>W</td>
<td>6</td>
<td>5G</td>
<td>W. Kuhn</td>
</tr>
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</table>

Objective

Content
- Mobile GIS
- Web-GIS & Geo-Web-Services
- Spatial Big Data
- Zeittliche Aspekte in GIS
- Analyse von Bewegungsdaten
- Benutzerschnittstellen

Spatial and Environmental Planning

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>103-0325-02L</td>
<td>Integrated Spatial Planning in Cities and Districts</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>G. Di Carlo Alvarez F. Güntcher</td>
</tr>
</tbody>
</table>

Objective
Methodische und instrumentelle Grundlagen der Raumentwicklung werden aus integratierter Sicht (Städtebau, Freiraum, Verkehr) vermittelt und von den Studierenden konkret in einem Zürcher Stadtquartier als Semesterübung angewendet.

Content
Die Studierenden lernen:
- Ein Repertoire an hilfreichen Werkzeugen sowie Denkmuster aus der Raumplanung kennenlernen
- Quartiere eigenständig zu erkunden, Potentiale sowie Risiken der Raumentwicklung zu erkennen und zu dokumentieren
- Eigene Räumliche Entwicklungskonzepte zu entwerfen und zu präsentieren
- Massnahmen für Schlüsselgebiete zu konkretisieren, u.a. hinsichtlich Zeitplanung, Organisation und Kosten

Traffic Systems

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Lecture notes
Vorlesungsstoff und Untitled werden auf Moodle hochgeladen.
The lecture series focuses on the physical principles and technical components of relevant systems for an efficient and sustainable transport. M. Wagner

**1. Introduction and overview**

Fundamentals: Infrastructures and vehicle technologies of public transport systems; interaction between track and vehicles; passengers and goods as infrastructure users; management and financing of networks.

**Communication**

**Energy and Climate Systems I**

Lecturers: W

**Hours**

assessed

not assessed

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahninfrastruktur; System- und Netzplanung

Lecture notes

The slides of the lecture serve as lecture notes and are available as download.

Literature

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahninfrastruktur; System- und Netzplanung

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

Techniques and Technologies

Domain B - Method-specific Competencies

Analytical Competencies

Decision-making

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Domain D - Personal Competencies

Adaptability and Flexibility

Creative Thinking

Critical Thinking

Integrity and Work Ethics

Self-awareness and Self-reflection

Self-direction and Self-management

_assessed

**Network Infrastructure**

**Number** 052-0609-00L

**Title** Public Transport and Railways

**Type** W

**ECTS** 3 credits

**Hours** 2G

**Lecturers** A. Nash, H. Orth, S. Schrani

**Abstract**

Fundamentals of public and collective transport, in its different forms, Categorization of performance dimensions of public transport systems, and their implications to their design and operations.

**Objective**

Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies. Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders. At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.

**Content**

Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

Vehicles: Classification, design and suitability for different goals

Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

**Lecture notes**

Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

Slides, in English, are made available some days before each lecture.

**Literature**

Reference material books are provided in German and English (list disseminated at lecture), plus Skript Bahninfrastruktur; System- und Netzplanung

**Network Infrastructure**

**Number** 052-0609-00L

**Title** Energy and Climate Systems I

**Type** W

**ECTS** 2 credits

**Hours** 2G

**Lecturers** A. Schlüter

**Abstract**

The first semester of the annual course focuses on physical principles, component and systems for the efficient and sustainable heating, cooling and ventilation of buildings on different scales and the interaction of technical systems with architectural and urban design.

**Objective**

The lecture series focuses on the physical principles and technical components of relevant systems for an efficient and sustainable climatisation and energy supply of buildings. A special focus is on the interrelation of supply systems and architectural design and construction. Learning and practicing methods of quantifying demand and supply allows identifying parameters relevant for design.

**Content**

1. Introduction and overview
2. Heating and cooling systems in buildings
3. Ventilation

**Lecture notes**

The slides of the lecture serve as lecture notes and are available as download.

**Literature**

A list of relevant literature is available at the chair.

**Electives**

**Electives ETH Zurich**

**Course Catalogue of ETH Zurich**

**Recommended Electives of Bachelor Degree Programme**
<table>
<thead>
<tr>
<th>Number</th>
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<td>W</td>
<td>4</td>
<td>9S</td>
<td>L. Hurni</td>
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<tr>
<td>Abstract</td>
<td>Independent scholarly piece based on up-to-date papers, text books, and internet sources. The thematic topic will be defined together with the supervision in the beginning.</td>
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<tr>
<td>Objective</td>
<td>Analysis and evaluation of text and other sources; structuring and writing a concise and reader-friendly seminar Report.</td>
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<td>W</td>
<td>8</td>
<td>17S</td>
<td>L. Hurni</td>
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<td>Abstract</td>
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**GESS Science in Perspective**

**Science in Perspective**

*see Science in Perspective: Type A: Enhancement of Reflection Capability*

*Recommended Science in Perspective (Type B) for D-BAUG*

**Language Courses**

*see Science in Perspective: Language Courses ETH/UZH*

**Bachelor’s Thesis**

<table>
<thead>
<tr>
<th>Number</th>
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<td>Bachelor’s Thesis</td>
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<td>10</td>
<td>21D</td>
<td>Lecturers</td>
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<tr>
<td>Abstract</td>
<td>Registration in myStudies by 15 January for theses during the spring semester, by 15 August for theses during the autumn semester.</td>
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</tr>
<tr>
<td>Objective</td>
<td>The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work.</td>
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<tr>
<td>Content</td>
<td>The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.</td>
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**Geospatial Engineering Bachelor - Key for Type**

<table>
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<th>Key</th>
<th>Type</th>
<th>Description</th>
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<td>O</td>
<td>Compulsory</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Suitable for doctorate</td>
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**Key for Hours**

<table>
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<th>Type</th>
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<tr>
<td>V</td>
<td>lecture</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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*European Credit Transfer and Accumulation System*

*Special students and auditors need special permission from the lecturers.*
Spatial Development and Infrastructure Systems Master

Master Studies (Programme Regulations 2021)

Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Abstract
History, impact and principles of the design and operation of transport systems.

Objective
Introduction of the basic principles of the design and operation of transport systems (road, rail, air) and of the essential pathways of their impacts (investment, generalised costs, accessibilities, external effects), referring to relatively constant, and factors with substantial future uncertainty, in the past and expected evolution of transport systems.

Content
Transport systems and land use; network design; fundamental model of mobility behaviour; costs and benefits of mobility; transport history and the importance of the design of transport systems.
Classification of public transport systems; Characteristics of rail systems, bus systems, cable cars and funiculars, unconventional systems; introduction to logistics; fundamentals of rail freight transports; freight transport systems; intermodal transportation.

Lecture notes
Lecturer notes and slides as well as hints to further literature will be given during the course.

Prerequisites / notice
Obligatory lecture for students of the first semester of MSc Spatial development and Infrastructure Systems.

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103-0317-00L Introduction to Spatial Development and Transformation

Abstract
The course deals with important theoretical, material and methodical foundations for action and decision-making of spatial relevance. This course discusses central tasks and possible solutions for current and future challenges of spatial development in Switzerland and Europe.

Objective
Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

Content
- Planning approaches and political organization in Switzerland
- Tasks of spatial relevance
- Key figures and ratios
- Drivers of spatial development
- Steering spatial development I: Policy
- Steering spatial development II: Formal and informal instruments
- Organizing spatial development I: Governance
- Organizing spatial development II: Processes and organization
- Methods in spatial planning I
- Methods in spatial planning II
- Planning in complex situations
- Participation in spatial development
- Present and future core tasks of spatial development

Lecture notes
Further information and the documents for the lecture can be found on the homepage of IRL/STL.

Taught competencies
- Concepts and Theories
- Techniques and Technologies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management
- Cooperation and Teamwork
- Critical Thinking
- Self-direction and Self-management

---

103-0347-00L Landscape Planning and Environmental Systems

Abstract
In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

Objective
The aims of this course are:
1) To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2) To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3) To show the importance of ecosystem services.
4) To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5) To identify and measure the characteristics of landscape.
6) Learn how to use spatial data in landscape planning.
In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

Lecture notes
No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice
The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

Taught competencies

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<tr>
<th>Domain A - Subject-specific Competencies</th>
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103-0377-10L | Basics of RE&IS
Only for Spatial Development and Infrastructure Systems
MSc.

Abstract
The course Basics of RE&IS provides essential basic knowledge for the Master's degree program in Spatial Development & Infrastructure Systems and is divided into the three main topics of technical-scientific working, writing & presenting. The students deepen and apply the learned knowledge in the context of three performance elements and one ungraded semester performance.

Objective
- The students can assess, discuss and explain the necessity, significance and application of the standards in scientific work.
- Students will be able to present their results in an engaging presentation together with their project group and use attractive and formally correct visualizations, maps or diagrams for this purpose.
- The students thus develop a common understanding with regard to their methodological knowledge and can henceforth work scientifically at an appropriate level.

Content
Students will learn the basics of scientific work and practice their skills within the framework of three performance elements as well as an ungraded semester work, which will be worked out in groups of two to three students.

In the first half of the semester, students will learn the theoretical basics and apply and understand these in the context of the exercises (=performance elements) in groups of maximum of two. The final ungraded semester exercise in the second part of the course, students will work in groups of maximum two on an assignment, which they will document and communicate in the form of a written report and a final presentation at the end of the course.

- Exercise 1: Citations & Referencing 20%
- Exercise 2: Searching, Reading and Summarizing 20%
- Exercise 3: Maps, Graphs & Visualizations 20%
- Exercise 4: Review 20%
- Presentation of review 20%

Students will be supervised by at least three assistants and one professor throughout the course. The main course lead changes periodically between the following RE&IS chairs: Infrastructure Management (IM), Transportation Systems (TS), Traffic Engineering (SVT), Transport Planning (VPL), Spatial Development and Urban Policy (SPUR), Planning of Landscape and Urban Systems (PLUS) and Spatial Transformation Laboratories (STL).

Lecture notes
All documents relevant for the course (slides, literature, further links, etc.) are provided centrally via the moddle platform.
Appropriate literature will be handed out when required via Moodle.

Spatial planners ensure our built environment optimally meets our future needs. This course explains how spatial planners can evaluate the use of Excel. Some students, however, prefer to use Python or R. The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least optimal maintenance strategies and network level constraints can be combined to determine optimal maintenance programs. These taking into consideration network level constraints, such as budgets. This week we demonstrate how the state of assets together with the intervention is planned than immediately afterwards, when it is in a like new state. This week we explain how optimal intervention strategies considering how to modify infrastructure to accommodate future needs, as it is easier to justify expenditures when a maintenance expectation is that the existing infrastructure is likely to provide service in the future, due to the uncertain environment in which we live, e.g. changing technologies and the changing climate. It is in the face of this complexity and uncertainty that spatial planners need to propose potential improvements and defend them convincingly to a large and diverse set of stakeholders.

The objective of this course is to provide spatial planners with an introduction to two essential tools in this regard. The first tool is a methodology to systematically take into consideration the future uncertainty in infrastructure requirements when proposing changes to the built environment. This involves the identification of key uncertainties, modelling their effect on infrastructure requirements and assessing how changes in future needs and the environment may affect future decisions. The second tool is a methodology to systematically estimate the life cycles of infrastructure assets. This methodology can be used together with the state of the existing infrastructure assets to develop optimal implementation plans.

More specifically, upon completion of the course students will understand how:

- to identify and quantify the service being provided by the built environment
- to construct an objective function to be used in the evaluation of proposed modifications
- to estimate changing societal needs and their potential effect on required infrastructure
- to develop concepts for flexible/robust infrastructure alongside traditional infrastructure
- to simulate future scenarios to evaluate the costs and effects on the service provided over time by infrastructure
- to estimate the service provided by existing infrastructure now and in the future
- to determine optimal maintenance strategies for infrastructure
- to convert them into optimal intervention programs, which can be used to build strong arguments as when to system modifications should be implemented.

The course consists of 9 lectures, 2 projects and 5 help sections. The two hour weekly lecture period is used as follows:

1. Planning infrastructure interventions – This lecture provides an introduction to the course and why it is useful in helping spatial planners propose and evaluate modifications to the built environment. The requirements for successful completion of the course are discussed and the two projects are introduced.

2. Service – Arguments for modifying the built environment are built on meeting the future needs of stakeholders. This week we present how to identify, quantify and value the service provided by the built environment. The measures of service, along with intervention costs are used to construct an objective function to be used in the evaluation of proposed modifications.

3. Changing needs – Trying to modify the built environment to meet future needs, requires estimating them. This week we discuss how to estimate them and their potential effect on required infrastructure.

4. Robust and flexible infrastructure – In the face of large amounts of future uncertainty it is useful to have either robust infrastructure, i.e. infrastructure that meets a large range of possible future needs, or flexible infrastructure, i.e. infrastructure that can be easily modified to meet different possible future needs. This week we discuss the concepts of robustness and flexibility and demonstrate their roles in maximizing the net-benefit of infrastructure.

5. Evaluating robust and flexible infrastructure – Robust and flexible infrastructure sometimes comes with increased costs. Whether or not the costs are worth it depends on a myriad of factors. This week we present a methodology that helps you develop robust and flexible infrastructure and evaluate their costs and benefits over time.

6. Simulating the uncertain future – As a key aspect to evaluating robust and flexible infrastructure is simulating what might happen in the future, this week, we explain how use Monte Carlo simulations and conduct an in class exercise so that you have an enhanced understanding of how it is done.

7. Help sessions 7-9 – We use the lecture periods to answer any questions you might have on project 1.

8. Existing infrastructure – Deciding how to modify infrastructure does not only require thinking about how to meet future needs. It also requires thinking about how the existing infrastructure is likely to provide service in the future. This week, we discuss the connection between provided service and the state of the infrastructure and use a common methodology to predict their evolution over time.

9. Maintenance strategies – It is useful to know the optimal maintenance intervention strategies for infrastructure assets but when considering how to modify infrastructure to accommodate future needs, as it is easier to justify expenditures when a maintenance intervention is planned than immediately afterwards, when it is in a like new state. This week we explain how optimal intervention strategies are estimated.

10. Maintenance programs – As planning periods approach, exact decisions need to be made as to which interventions will be executed, taking into consideration network level constraints, such as budgets. This week we demonstrate how the state of assets together with the optimal maintenance strategies and network level constraints can be combined to determine optimal maintenance programs. These programs are used to optimally integrate both maintenance and modification interventions into one intervention program.

11. Help sessions 13 and 14 – We use the lecture periods to answer any questions you might have on project 2.

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least the use of Excel. Some students, however, prefer to use Python or R. The lecture materials will be distributed via Moodle two days before each lecture.

Appropriate literature will be handed out when required via Moodle.
103-0378-00L Introduction to the Programming Language R

Abstract
R is one of the most popular programming language in science and practice for data analysis, modelling and visualisation. In this course, you will learn the basics of R and some common applications of R, such as making plots, regression analysis and working with spatial data. The weekly computer labs start with a short lecture followed by exercises that have to be handed in to pass the course.

Objective
The overall objective of this course is to provide an introduction to the programming language R and to build confidence to apply R in other courses. More specifically, the objectives are:
- Understand how to import and export data, and how to work with the most important types of R-objects (e.g. vectors, data frames, matrices and lists).
- Learn how to create meaningful and visually attractive graphics and apply this knowledge to several datasets.
- Learn how to apply several types of important functions (e.g. for- and while-loops, if-else statements, data manipulation).
- Understand descriptive statistics and regression analysis and apply this knowledge to analyse several datasets.
- Understand the possibilities of analysing and plotting spatial data.
- Learn how to write own functions.

Content
The course has a strong focus on “learning by doing”. During the weekly computer lab sessions, students will be given an introduction to the programming language R. Each lab session will start with a short introductory lecture, after which students work through the script and complete the exercises. During the lab sessions, the lecturers will be available to answer individual questions. The main topics that will be covered in the lab sessions are:
- importing and exporting data
- types of R-objects
- data scraping
- plotting data
- descriptive statistics
- data manipulation
- conditionals and loops
- regression analysis
- plotting and analysing spatial data
- writing own functions

Lecture notes
A script with theory, examples and exercises will be handed out at the beginning of the course. Data for the exercises will be made available via Moodle.

Literature

Prerequisites / notice
No prior knowledge of R or any other programming language is required for this course.

Major Courses
Major in Spatial and Landscape Development

Number Title Type ECTS Hours Lecturers
103-0337-00L Site and Project Development W 3 credits 2G A. Gonzalez Martinez, M. Sudau, J. Van Wezemael

Abstract
The focus of the lecture Site & Project Development is on larger contiguous areas or sites and their urban, open space and infrastructural development. In this course, students work on a semester exercise in which they “develop” a specific large-scale project from practice and evaluate it economically, strategically and in terms of feasibility.
Students in this course will pursue the following learning objectives:

- Investigate and understand a given concrete project area and identify, evaluate and articulate the current problems and relevant issues within this area.

- Consolidate their knowledge in the essential topics of site & project development and apply this in a well-founded, argued and creative manner to address the task at hand.

- Organize and structure themselves while acquiring responsibilities in their interdisciplinary project teams. The teams consist of three to five fellow students that must develop innovative, viable and resilient concepts for a real project development in a given area. Their considerations should be presented in written form (project report) and in linguistic-visual form (final presentation). At the end of the course, the students critically reflect on their experiences with the group work process together with the course instructors.

- Acquire methodological knowledge in location & market analysis, 3D visualization of a project as well as in the financial assessment of a large-scale real estate project and use this knowledge to justify their considerations and evaluate their proposal.

- Development and strengthening of their individual position as planners (spatial, urban, transport planners, etc.) in relation to the questions formulated in the proposed project within the field of Site & Development as well as within their own discipline.

The lecture is divided into several thematic sections analogous to the essential topics of Site & Project Development. The students are accompanied both in the semester exercise and in the individual lectures by a large number of external guest speakers from the praxis-field, which means that the lecture will not only thematically examine the relevant areas of Site & Project Development, but also will offer the students exclusive, practice-oriented insights. The relevant methodological knowledge for the semester exercise is imparted and, due to the proximity to practice, the students gain exclusive insights into possible professional fields of activity. In this lecture, students apply their already acquired and newly learned skills, especially in interdisciplinary teams, and work on an exciting, motivating and relevant question from the practice.

Major topics covered in the lecture include:
- Urban planning
- Location and market analysis
- Real estate development, financing and valuation
- Project development and decision-making from the perspective of investors
- Open space design and landscape architecture
- Sustainable building and sustainability certification
- Mobility, parking issues, travel models
- Cooperative planning and participation processes, mediation
- Gendered planning in project development
- Inner development & urban quality
- Urban data science
- Legal, financial and fiscal aspects
- Development and strengthening of their individual position as planners (spatial, urban, transport planners, etc.) in relation to the questions formulated in the proposed project within the field of Site & Development as well as within their own discipline.

Parallel to the lecture series, students work in interdisciplinary teams on a real-life task. In the course of the semester exercise, the lecture material is deepened and what has been learned is applied. The students visit the project area at the beginning of the semester as part of an excursion. Specific large-scale projects such as the Gaswerkareal Bern, the Sihl-Manegg Areal Zurich (Greencity) or the Areal Alter Pilatusmarkt (Nidfeld) Lucerne will be dealt with. For the possible development of the given site, visions are developed by the students on the basis of a comprehensive location and market analysis and a utilization concept is developed. In the process, the students are accompanied by experts and regularly discuss their ideas and proposed solutions with their supervisors.

The relevant methodological knowledge for the semester exercise is imparted and, due to the proximity to practice, the students gain exclusive insights into possible professional fields of activity. In this lecture, students apply their already acquired and newly learned skills, especially in interdisciplinary teams, and work on an exciting, motivating and relevant question from the practice.

In this course, students are offered interdisciplinary knowledge from planning practice and research, behavioural economics and social sciences. New perspectives on planning are opened up, which can lead to better results in future projects and research.
Objective

Keeping the general aim of exploring the basic methodologies in spatial planning research and practice, the specific course learning objectives are as follows:

- to address complex real-world spatial problems in adequate ways
- to know relevant theories and maxims that are subject to specific methods of problem solving
- to identify key questions and key concepts in contemporary planning research
- to select appropriate research methods to properly address the research questions

In practical terms, students:
- learn to deal with uncertainties and estimate quantities
- improve their ability to take decisions based on incomplete data and information
- are informed about different (qualitative and quantitative) methods and techniques for spatial research
- learn about different types of research (theoretical, empirical, action-oriented, qualitative, quantitative)
- get skilled for writing simple research essays
- are urged to question their own knowledge and challenge the course of action taken in planning processes

Content

The course is based on the following questions:

How do we deal with complex issues in planning?
- Forms of knowledge, half-knowledge and not knowing
- Occurrence and explanation patterns for irrational behaviour
- Spatial research and planning practice
- Planning maxims
- Mapping complex topics in research questions

How do we generate knowledge about complex issues?
- Methods for scientific data generation
- Applied handling of quantities and probabilities
- Estimating despite uncertainties
- Opportunities of digitisation in planning (Participation, BigData)

How do we react to complex questions in planning?
- Methods of scientific data analysis
- Making decisions despite incomplete information
- Dealing with robustness and fragility

More specifically, the lectures focus on the following topics (NB: Some content units will be presented in English, they are marked with *asterisk below)

- (Half-) knowledge/behaviour/irrationalities
- Initial situation: Solving complex problems
- Forms of knowledge, knowing of not knowing something, not knowing of not knowing something
- Behavioural patterns, occurrence and explanation patterns for irrational behaviour
- Methods for solving complex tasks in planning practice
- Spatial research and planning practice - connections, differences, overlaps
- Challenges in the solution of complex tasks: System delimitation, interdisciplinarity, retrospective vs. prospective approach (descriptive vs. action-oriented, “reflected scenario building”)
- Planning maxims
- *Methodology in spatial research
- *Research design
- *Research questions (types of research questions; research questions, hypotheses and theories); justification of research question
- Data generation methods (interviews and questionnaires, ethnography and observation, documents, official statistics)
- Dealing with quantities, estimations, anchor effect
- Importance of scales and key figures in planning
- Estimation methods
- Danger of the anchor effect
- Digitization in planning
- New data sources and sizes
- Opportunities and challenges through digitisation in planning
- Quantitative analysis of survey data; qualitative analysis - content analysis, discourse analysis, case study, comparative research
- *Research ethics
- *Role of science in planning - the perspective of both research and practice

Lecture notes

Learning materials: available online (Moodle) before corresponding lecture.

Literature

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

851-0707-00L  Space Planning Law and Environment
- Particularly suitable for students of D-ARCH, D-BAUG, D-USYS
- W 2 credits 2G O. Bucher

Abstract
System of swiss planning law, Constitutional and statutory provisions, Space planning and fundamental rights, Instruments, Application, legal protection, enforcement, Practical training.

Objective
Basic understanding of nature and function of space planning from a legal point of view. Basic knowledge of space planning instruments, relationship between space planning and constitutional law (especially property rights), solving of practical cases.

Content

Lecture notes
Handouts will be available.

Literature
Haller, Walter/Karlen, Peter, Raumplanung-, Bau- und Umweltrecht, 3.A., Zürich 1999
Hänni, Peter, Planungs-, Bau- und besonderes Umweltschutzrecht, 6.A., Bern 2016

103-0327-00L  History of Spatial Planning
- W 3 credits 2V M. Koll-Schretzenmayer

Abstract
This course aims to provide students with knowledge of the historical background to understand the current spatial structure and to face the current channales in spatial planning. Social, cultural, and economic forces will be analyzed for the roles they have played in shaping the landscapes and cityscapes and the answers spatial planning had to spatial development. The course focuses on the history of planning ideas, paradigms and approaches. A link is made to current challenges in spatial planning. Students will critically discuss the challenges spatial planning is facing today.

Objective
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making

Lecture notes
Daniel Kurz: Die Disziplinierung der Stadt - Moderner Städtebau in Zürich 1900 bis 1940. gta Verlag 2008

103-0569-00L  European Aspects of Spatial Development
- W 3 credits 2G A. Peric Momcilovic

Abstract
Following the insight into historical perspective and contemporary models of governance and planning, the course focuses on the international dimension of spatial planning in Europe. This includes a discussion of how European spatial policy is made and by whom, how planners can participate in such process and how they can address transnational challenges of spatial development cooperatively.

Objective
Keeping the general aim of exploring the European dimension of spatial planning in mind, the specific course learning objectives are as follows:
- to interpret the history of spatial planning at the transnational scale
- to understand and explain the content of the European spatial policy agenda
- to describe and analyse the role of territorial cooperation in making European spatial development patterns and planning procedures
- to discuss the changing role of planners and evaluate the ways of their engagement in European spatial policy-making
The documents for the lecture will be provided at the moodle.

A. Grêt-Regamey

Analytical Competencies
- European spatial policy agenda: introduction and basic directives
- governance models
- planning models; collaborative planning model (main concepts & critics)
- post-positivist approach to spatial planning
- transnational spatial planning in Europe; questioning the European spatial planning; spatial development trends in Europe
- EU as a political system: EU institutions & non-EU actors
- planning families in Europe; the European spatial planning agenda
- spatial planning strategies and programmes on territorial cooperation
- the Europeanization of culture and planning system: planning cultures in Europe
- basic characteristics of planning systems in Europe
- the relevance of European transnational cooperation for spatial planning
- European transnational initiatives

2U

Concepts and Theories
- Self-direction and Self-management
- Self-awareness and Self-reflection
- Integrity and Work Ethics
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Creativity
- Sensitivity to Diversity
- Self-direction and Self-management

W

103-0347-01L Landscape Planning and Environmental Systems (GIS W 3 credits 2U A. Grêt-Regamey, C. Brouillet, N. Klein

Exercises) ■

Abstract
The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

Objective
- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies

Autumn Semester 2021

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The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census
methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and
procedures. Birds and plants are used as main example guiding through different case studies.

Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It
explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to
their uptake.

Objective
Students should be able to
a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social
dimensions across relevant temporal and spatial scales.
b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and
resource management.

Content
Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional
management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These
failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-
dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple
spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem
management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands
of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to
economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management
systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on
underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-
being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests,
agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic
development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic
uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems
will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to
alternative livelihood options and marketing strategies of common pool resources.

Lecture notes
No Script

Literature

701-1543-00L
Ecological Assessment and Evaluation
W 3 credits 3G F. Knaus

Objective
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

Lecture notes
Powerpoint slides are available on the webpage. Additional documents are handed out as copies.

Literature
Basic literature and references are listed on the webpage.
**052-0705-00L**  
**Landscape Architecture I**  
**W** 2 credits  2V  D. Richter

**Abstract**  
Introduction to the history and theory of garden design and landscape architecture. Analysis of the design of historical gardens and landscapes within the cultural background.

**Objective**  
The course covers the basic history and theory of garden design and landscape architecture from its beginnings to the 21st century. The course aims to raise awareness of a changing perception of nature and landscape.

**Content**  
The lecture series on History and Theory of Garden Design and Landscape Architecture deals with the historical development of designed nature, from the beginnings of cultural landscapes and gardens to 21st century landscape architecture. In the analysis of each era, the focus is on the spatial and cultural relationship between the garden, the city and the landscape, as well as the changing perceptions of nature and its representation.

**Exchange students or students from other departments:** Students, who are attending only one semester, may pass the oral end-of-semester examination. Test-relevant literature will also be made available for download for this purpose. The students are requested to get in touch by email with the Chair.

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**053-0468-00L**  
**Participatory Modeling in Integrated Landscape Development**  
**W** 3 credits  2G  E. Celio, N. Salliou

**Abstract**  
The lecture accompanies students into a participatory modelling process. We explore topics such as urban agriculture or climate-resilient city. Students will know participatory modelling tools as well as concepts and approaches related to it. Students elaborate the processes from questions to interactive operational models. The students are requested to get in touch by email with the Chair.

**Taught competencies**  

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<td><strong>Domain D - Personal Competencies</strong></td>
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<tr>
<td>Self-direction and Self-management</td>
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**102-0317-00L**  
**Advanced Environmental Assessments**  
**W** 3 credits  2G  S. Pfister, R. Frischknecht

**Abstract**  
Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0317-00 Advanced Environmental Assessments (3KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

**Objective**  
This course deepens students’ knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the - Ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers

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**Prerequisites / notice**  
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

**Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:**  
- Pflanzen- und Vegetationsökologie  
- Systematische Botanik  
- Raum- und Regionalentwicklung  
- Naturschutz und Naturschutzbiozologie

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Content
- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multioutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

Lecture notes
No script. Lecture slides and literature will be made available on Moodle.

Literature
Literature will be made available on Moodle.

Prerequisites / notice
Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

063-0703-00L Architecture of Territory: Territorial Design in Histories, Theories and Projects

This core course (ending with «00L») can only be passed once! Please check before signing up.

Abstract
This lecture series sets up an agenda for widening the disciplinary field of architecture and urbanism from their focus on the city, or the urban in the narrow sense, to wider territorial scales, which correspond to the increasing scales of contemporary urbanisation. It discusses the concepts of territory and urbanisation, and their implications for the work of architects and urbanists.

Objective
The course will enable students to critically discuss concepts of territory and urbanisation. It will invite students to revisit the history of architects’ work engaging with the problematic of urbanising territories and territorial organisation. The goal is to motivate and equip students to engage with territory in the present day and age, by setting out our contemporary urban agenda.

The lectures are animated by a series of visual and conceptual exercises, usually on A4 sheets of paper. All original student contributions will be collected and bound together, creating a unique book-object. Some of the exercises are graded and count as proof of completion.

Content
Within the theme My Species, the four guest speakers engaged in fields ranging from art and landscape representation to bioethics and environmental philosophy, will approach territory through the notions such as multispecies, coexistence, and diversity. With a more-than-human perspective on the territory, the guest speakers will elaborate their take on “telling horrible stories in beautiful ways,” debate “the dignity of plants,” expound upon “mankind’s fascination to better the world,” and confer “the non-human turn” and what is to come after.

23. 09. 2021
On Territory
MILICA TOPALOVIĆ

30. 09. 2021
Architecture and Urbanisation
MILICA TOPALOVIĆ

07. 10. 2021
Methods in Territorial Research and Design
MILICA TOPALOVIĆ

14. 10. 2021
Multispecies Worldbuilding
Guest lecture by FEIFEI ZHOU

21. 10. 2021
Better Nature
Guest lecture by ALEXANDRA DAISY GINSBERG

04. 11. 2021
Planetary Urbanisation: Hinterland
MILICA TOPALOVIĆ

11. 11. 2021
Tomatoes Talk, Birch Trees Learn – Do Plants Have Dignity?
Guest lecture by FLORIANNE KOECHLIN

18. 11. 2021
Disappearance of the Countryside
MILICA TOPALOVIĆ

25. 11. 2021
What is Soul? On the Idea of Species Being
Guest lecture by OXANA TIMOFEEVA

09. 12. 2021
Our Common Territories: An Outlook
MILICA TOPALOVIĆ
Prerequisites / notice

The lectures will take place on Thursdays, 10.00-12:00, at ONA Fokushalle E7 and on ZOOM.

Lecturer:
Prof. Milica Topalovic

Team:
Prof. Milica Topalovic, Nazli Tümerdem, Vesna Jovanović

Contact:
Nazli Tümerdem
tuemerdem@arch.ethz.ch

Our website:
https://topalovic.arch.ethz.ch

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Communication assessed
Self-presentation and Social Influence assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Self-awareness and Self-reflection assessed

Major in Transport Systems and Behaviour

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0427-01L</td>
<td>Public Transport Design and Operations W</td>
<td>6 credits</td>
<td>4G</td>
<td>F. Corman, F. Leutwiler</td>
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Abstract

This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system. Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Objective

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders.

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

Content

General structure:
general introduction of transport, modes, technologies, system design and line planning for different situations, mathematical models for design and line planning

timetabling and tactical planning, and related mathematical approaches
operations, and quantitative support to operational problems, evaluation of public transport systems.

Planning process, from demand evaluation to line planning to timetables to operations

Matching demand and modes
Line planning techniques
Timetabling principles

Allocation of resources
Management of operations
Measures of realized operations
Improvements of existing services

Lecture notes

Lecture slides are provided.

Literature

Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)


The course provides the necessary knowledge to develop models supporting the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

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<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<td>Decision-making</td>
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<td>Media and Digital Technologies</td>
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<td>Domain C - Social Competencies</td>
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<tr>
<th>Subject</th>
<th>Domain</th>
<th>Taught competencies</th>
<th>Content</th>
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<tbody>
<tr>
<td>Transport Planning Methods</td>
<td>W</td>
<td>4 credits</td>
<td>Weekly: 1h independent preparation; 2h lectures and 1h training with an expert in the respective field</td>
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<tr>
<td>101-0417-00L</td>
<td>6 credits</td>
<td>4G</td>
<td>K. W. Axhausen</td>
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</table>

### Lecture notes

**Moodle platform (enrollment needed)**


### 101-0437-00L Traffic Engineering

**W 6 credits 4G A. Kouvelas**

**Abstract**
Fundamentals of traffic flow theory and control.

**Objective**
The objective of this course is to fully understand the fundamentals of traffic flow theory in order to effectively manage traffic operations. By the end of this course students should be able to apply basic techniques to model different aspects of urban and inter-urban traffic performance, including congestion.

**Content**
Introduction to fundamentals of traffic flow theory and control. Includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.

**Lecture notes**
The lecture notes and additional handouts will be provided during the lectures.

**Literature**
Additional literature recommendations will be provided during the lectures.

**Prerequisites / notice**
Verkehr III - Road Transport Systems 6th Sem, BSc (101-0415-00L)

Special permission from the instructor can be requested if the student has not taken Verkehr III

### 227-0523-00L Railway Systems I

**W 6 credits 4G M. Meyer**

**Abstract**
Basic characteristics of railway vehicles and their interfaces with the railway infrastructure:
- Transportation tasks and vehicle types
- Running dynamics
- Mechanical part of rail vehicles
- Brakes
- Traction chain and auxiliary supply
- Railway power supply
- Signalling systems
- Standards
- Availability and safety
- Traffic control and maintenance

**Objective**
- Overview of the technical characteristics of railway systems
- Know-how about the design and construction principles of rail vehicles
- Interrelationship between different fields of engineering sciences (mechanics, electro and information technology, transport systems)
- Understanding tasks and opportunities of engineers working in an environment which has strong economical and political boundaries
- Insight into the activities of the railway vehicle industry and railway operators in Switzerland
- Motivation of young engineers to start a career in the railway industry or with railway operators

**Content**
EST I (Herbstsemester) - Begriffen, Grundlagen, Merkmale

1. Einführung:
   1.1 Geschichte und Struktur des Bahnsystems
   1.2 Fahrdynamik

2. Vollbahnhäufige:
   2.1 Mechanik: Kasten, Drehgestelle, Lauftechnik, Adhäsion
   2.2 Bremsen
   2.3 Traktionsantriebssysteme
   2.4 Hilfsbetriebe und Komfortanlagen
   2.5 Steuerung und Regelung

3. Infrastruktur:
   3.1 Fahrweg
   3.2 Bahnstromversorgung
   3.3 Sicherungsanlagen

4. Betrieb:
   4.1 Interoperabilität, Normen und Zulassung
   4.2 RAMS, LCC
   4.3 Anwendungsbeispiele

Voraussichtlich ein oder zwei Gastreferate

Geplante Exkursionen:
Betriebszentrale SBB, Zürich Flughafen
Reparatur und Unterhalt, SBB Zürich Altstetten
Fahrzeugfertigung, Stadler Bussnang

**Lecture notes**
Abgabe der Unterlagen (gegen eine Schutzgebühr) zu Beginn des Semesters. Rechtzeitig eingeschriebene Teilnehmer können die Unterlagen auf Wunsch und gegen eine Zusatzgebühr auch in Farbe beziehen.

**Prerequisites / notice**
Dozent: Dr. Markus Meyer, Emkamatik GmbH

Voraussichtlich ein oder zwei Gastvorträge von anderen Referenten.

EST I (Herbstsemester) kann als in sich geschlossene einsemestrige Vorlesung besucht werden. EST II (Frühjahrssemester) dient der weiteren Vertiefung der Fahrzeugtechnik und der Integration in die Bahninfrastruktur.

### Taught competencies

**Domain A - Subject-specific Competencies**
- Concepts and Theories assessed

**Domain B - Method-specific Competencies**
- Techniques and Technologies assessed

**Domain D - Personal Competencies**
- Critical Thinking assessed
This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and how transport infrastructure investments can affect the location, size, and composition of such systems.

Objective

The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems (i.e., agglomeration and congestion forces), and the role of transport networks in shaping the structure of these systems. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after having completed the course.

Content

The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1950 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong microfoundations and allow for precise policy recommendations.

Lecture notes

Course slides will be made available to students prior to each class.

Literature

Course slides will be made available to students to prior to each class. Course slides will be made available to students prior to each class.

101-0492-00L Microscopic Modelling and Simulation of Traffic Operations

Abstract

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

Objective

The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:

- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.).
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.

Content

In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:

1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:

1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibration and validating the simulation model.
3) Redesigning/extensiong the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The modern software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

Lecture notes

The lecture notes and additional handouts will be provided before the lectures.

Literature

Additional literature recommendations will be provided at the lectures.

Prerequisites / notice

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

101-0491-00L Agent Based Modeling in Transportation

Abstract

This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.

Objective

At the end of the course, the students should:
- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform practical transportation studies
Content
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained
4) Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).

Literature
Agent-based modeling in general
MATSim

Prerequisites / notice
There are no strict prerequisites in terms of which lectures the students should have previously attended. However, knowledge of basic statistical theory is expected, and experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

101-0469-00L Road Safety W 6 credits 4G M. Deublein, P. Eberling
Abstract
The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety Aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.

Objective
Improve knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

Content
Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and reliability measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

Literature
Basic literature: message Via sicura; Directive 2008/96/EC on road infrastructure safety management; ELVIK, R.; VAA, T. (2004). The Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and reliability measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

Network Infrastructure

101-0549-00L Selected Topics on Legal Aspects in Civil Engineering W 3 credits 2G H. Briner, D. Trümpy
Abstract
Basic knowledge in public and private law of civil engineering. Examples of the subjects treated: space management, protection of the environment, legal procedures, standards for building technology and contracts.

Objective
Part 1: The students shall acquire basic knowledge of the public law concerning civil engineering:

Part 2: The students shall acquire basic knowledge of the private law concerning civil engineering

Content
Teil 1: Jede Lektion behandelt für ein bestimmtes Stadium des Projekts ein Thema des öffentlichen Baurechts wie Bau- und Zonenordnungen, Quartierpläne, Umweltverträglichkeitsprüfungen, Baubewilligungsverfahren etc.

Teil 2: Grundzüge des privaten Baurechts wie Abnahme und Genehmigung von Bauwerken, Vollmacht des Architekten / Ingenieurs zu Rechtshandlungen namens des Bauherrn, Mängelrüge im Bauwesen, Mehrheit ersatzpflichtiger Baubeteiligter, Generalunternehmervertrag, Haftung des Bauproduktionsverlages, Bauhandwerkerpfandrecht, Grundzüge der SIA-Norm 118, Raumordnung, technische Normen, internationale Bauverträge, Architekten / Ingenieure als Gerichtsexperten, Aspekte des Bauvollzugsverfahrens,

Lecture notes
D. Trümpy, Tafeln zu den Grundzügen des Schweizerischen Bauvertragsrechts (Vorlesungsunterlage) H. Briner, Tafeln zu den Grundzügen des öffentlichen Raumplanungs-, Bau- und Umweltrechts (Vorlesungsunterlage)

Literature
- Stöckli P./Siegenthaler Th. (Hrsg.) Die Planerverträge, Schulthess 2013
- Gauch Peter, Werkvertrag, 5. Auflage, Schulthess 2011

Prerequisites / notice
Die Teilnehmer sollen stets ein Exemplar der SIA-Norm 118, der SIA-LHO 103 sowie die Gesetzessgaben von OR und ZGB bei sich haben.

101-0492-00L Microscopic Modelling and Simulation of Traffic W 3 credits 2G M. Makridis
Operations
The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

Objective
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Aimsun software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:

- Understand the basic models used in simulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.)
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.
Content

In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun.

Microscopic modelling and simulation concepts will include:
1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:
1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/extend the model to improve the traffic performance through Aimsun and with/without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students.

It consists of weekly 2-hour lectures. The students work in pairs on a group project that completes in the end of the semester. The moulding software used is Aimsun and lectures (theory and hands on experiences) are taking place in a computer room.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

Lecture notes

The lecture notes and additional handouts will be provided before the lectures.

Literature

Additional literature recommendations will be provided at the lectures.

Prerequisites / notice

Students need to know some basic road transport concepts. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>ECTS</th>
<th>Credit</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0469-00L</td>
<td>Road Safety</td>
<td>6</td>
<td></td>
<td>M. Deublein, P. Eberling</td>
</tr>
<tr>
<td>101-0419-02L</td>
<td>Railway Infrastructures 2</td>
<td>2</td>
<td>2G</td>
<td>U. A. Weidmann, P. Gültenapfel, M. Köhler, M. J. Manhart</td>
</tr>
<tr>
<td>363-0701-00L</td>
<td>Methods of Urban Research</td>
<td>2</td>
<td></td>
<td>C. Schmid, I. Apostol, N. Bathia, L. Howe, C. Ting</td>
</tr>
<tr>
<td>363-0541-00L</td>
<td>Systems Dynamics and Complexity</td>
<td>3</td>
<td></td>
<td>F. Schweitzer</td>
</tr>
</tbody>
</table>

Abstract

1) Track geometry including calculation and measuring as well as related data systems; clearance profiles; interaction between track and vehicles; vehicle dynamics, stress; track construction including special features of railway bridges and tunnels; environmental aspects in track construction; track diagnostics and forecast; track maintenance and related methods

2) Interaction

Interaction between track and vehicles, vehicle dynamics

3) Railway Track

Stress; track construction including special features of railway bridges and tunnels

4) Environmental aspects in track construction

Fundamentals; noise protection; vibration protection

5) Diagnostics, maintenance strategies

Track diagnostics and forecast; maintenance strategies

6) Track maintenance

Fundamentals of track maintenance and related methods

Lecture notes

The slides will be made available.


Literature

A list with related technical literature will be handed out.

Prerequisites / notice

Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)

Major Courses for all Majors

<table>
<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>063-0701-00L</td>
<td>Methods of Urban Research</td>
<td>4</td>
<td></td>
<td>C. Schmid, I. Apostol, N. Bathia, L. Howe, C. Ting</td>
</tr>
<tr>
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<td>Systems Dynamics and Complexity</td>
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<td>F. Schweitzer</td>
</tr>
</tbody>
</table>

Abstract

This course aims at enabling students of architecture to use sociological analysis as basis for concrete projects in architecture and urban design. It is based on a specific set of methods that is applied in design studios (integrated disciplines) as well as in the master thesis (supplementary discipline sociology).

This core course (ends with <00L>) can only be passed once! Please check this before signing up

This course conveys an introduction into methods of urban research in social sciences through lectures and accompanying exercises. It treats the basic principles of scientific research, literature research, different forms of participant observation, qualitative interviews (expert interviews and ethnographic interviews), and the analysis of urban qualities.

Implementing solutions: project management, critical path method, quality control feedback loop.

Implementing solutions: project management, critical path method, quality control feedback loop.
A successful participant of the course is able to:
- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics

What are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical systems dynamics, nonlinear dynamics and macroeconomic modeling.

The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as home work and two of these will be graded (see "Prerequisites").

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture

### Interdisciplinary Project Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0020-00L</td>
<td>Interdisciplinary Project Only for Spatial Development and Infrastructure Systems MSc, Programme Regulations 2021...</td>
<td>O</td>
<td>16 credits</td>
<td>34A</td>
<td>A. Grêt-Regamey</td>
</tr>
</tbody>
</table>

#### Abstract

The Interdisciplinary Project Activity (IPA) forms the key feature of the MSc RE&IS. Students work on an interdisciplinary task from the field of spatial development and infrastructure systems in a real application area. The focus of the IPA on interdisciplinary cooperation and strong communication skills are crucial expertise required in practice to communicate with and between relevant actors.

#### Objective

Upon completion of the IPA, students have developed skills in:

1) Investigating and understanding a given project area in a real-world context as well as identifying, evaluating and formulating the current issues and relevant topics within that area.

2) Creating, designing/developing and evaluating an overall integrated strategy for the project area with relevant measures as well as an in-depth study of a certain area or topic within the project area visualizing, describing, presenting and reporting on these in a written project report.

3) Organising, structuring and promoting team work within an interdisciplinary group of 4-5 students in self-responsibility.

4) Applying previously learnt interdisciplinary methodological and theoretical skills from different fields as well as methods and design thinking learnt during the IPA.

5) Evaluating and choosing the right way of representation (e.g.: text, statistics, images, etc.) for all pieces of information, ideas and proposals throughout the whole semester.

6) Understanding, developing and strengthening and critically self-evaluating their individual disciplinary position and role.

Students apply the full range of their previously learned theoretical and methodological skills to solve the task together in their project team. Working closely with representatives of the case study area (e.g. officials, the wider public, different experts and decision-makers), which changes annually, as well as other experts, through site visits, and through individual mentoring by the six RE&IS chairs, students work in a stimulating and motivating environment to solve real-world spatial challenges.

- The semester is structured through an intermediate and final presentation, bilateral discussions with the chairs involved as well as individual group mentoring. On these meetings, the work status has to be communicated with adequate representational means and is discussed with the professors, assistants and possibly external experts.

- The project begins with a site visit of the project area at the beginning of the semester and the identification as well as precise formulation of the issues and opportunities observed within the project area.

- The students work on a complex, rather rough task and define their exact objective independently on the basis of the as-is analysis. In the overall strategy, the future development direction for the project area is then determined and measures are formulated to steer the development in this direction. Within a focus area or focus topic, students further develop their project and deepen their overall strategy. They test and evaluate the impact of selected measures and finally reflect on their project, summarize the most important findings and make a recommendation formulated to decision-makers.

- The project gets developed in an interdisciplinary group of students. The internal structuring of the group and distribution of work is to be organised by the students themselves.

- The choice of software for the project development is up to the students. The software used should be applicable to data analysis, information processing, image production and word processing. This can include the Adobe programs such as InDesign, Illustrator or Photoshop, GIS, the Microsoft programs such as Word, PowerPoint or Excel, CAD, R, etc.)
Master's Thesis

**Number** | **Title** | **Type** | **ECTS** | **Hours** | **Lecturers**
---|---|---|---|---|---
103-0010-10L | Master's Thesis<br>Only for Spatial Development and Infrastructure Systems MSc, Programme Regulations 2021. | O | 20 credits | 43D | Supervisors

*Before starting the Master's thesis, students must have*
- a. obtained the Bachelor's degree;
- b. fulfilled all specified admission conditions, if any;
- c. acquired at least 90 credits in the Master's programme, including the credits in the mandatory courses and 12 credits in the area of the interdisciplinary project.

**Abstract**
The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

**Objective**
To work independently and to produce a scientifically structured work.

**Content**
The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

Master Studies (Programme Regulations 2009)

**Major Courses**

**Major in Spatial and Landscape Development**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th><strong>Type</strong></th>
<th><strong>ECTS</strong></th>
<th><strong>Hours</strong></th>
<th><strong>Lecturers</strong></th>
</tr>
</thead>
</table>
| 103-0468-00L | Participatory Modeling in Integrated Landscape Development | W | 3 credits | 2G | E. Celio, N. Salliou

**Abstract**
The lecture accompanies students into a participatory modelling process. We explore topics such as urban agriculture or climate-resilient city. Students will know participatory modelling tools as well as concepts and approaches related to it. Students elaborate the processes from questions to interactive operational models.

**Objective**
With this course, students ...
- ... know the phases of a participatory modelling process
- ... are able to estimate in which case the involvement of stakeholders is necessary, hence are able to discuss advantages and disadvantages of stakeholder involvement at different levels of participation,
- ... get to know diverse modelling tools and are able to select the proper tool according to the context,
- ... are able to set-up and apply a functional model in a participatory manner on a real case study,
- ... get to know techniques to analyse simulations and are able to inform stakeholders in an adequate way.
- ... are able to discuss results together with stakeholders in a structured way.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Competencies</th>
<th>Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th>Competencies</th>
<th>Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>not assessed</td>
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<thead>
<tr>
<th>Domain C - Social Competencies</th>
<th>Competencies</th>
<th>Taught</th>
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</thead>
<tbody>
<tr>
<td>Communication</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
<td></td>
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<tr>
<td>Negotiation</td>
<td>not assessed</td>
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<table>
<thead>
<tr>
<th>Domain D - Personal Competencies</th>
<th>Competencies</th>
<th>Taught</th>
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</thead>
<tbody>
<tr>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
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<tr>
<td>Creative Thinking</td>
<td>assessed</td>
<td></td>
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<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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<tr>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
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</tr>
<tr>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
<td></td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
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Global History of Urban Design I

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<tr>
<th>Number</th>
<th>Title</th>
<th><strong>Type</strong></th>
<th><strong>ECTS</strong></th>
<th><strong>Hours</strong></th>
<th><strong>Lecturers</strong></th>
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</thead>
</table>
| 052-0801-00L | Global History of Urban Design I | W | 2 credits | 2G | T. Avermaete

**Abstract**
This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advancements.

**Objective**
The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students' future design work.

**Content**
In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

- 01. The History and Theory of the City as Project
- 02. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
- 03. The Idea of the Polis: Rome, Greece and Beyond
- 04. The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
- 05. Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
- 06. Of Absolutism and Enlightenment: Baroque, Defense and Colonization
- 07. The City of Labor: Company Towns as Cross-Cultural Phenomenon
- 09. Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
- 10. Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
- 11. The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid
Lecture notes
Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

Literature
There are three books that will function as main reference literature throughout the course:


These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

Prerequisites / notice
Students are required to familiarize themselves with the conventions of architectural drawing (reading and analyzing plans at various scales).

majors

### Major in Transport Systems and Behaviour

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0445-00L</td>
<td>Production and Operations Management</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>T. Netland</td>
</tr>
</tbody>
</table>

**Abstract**
This course provides students a broad theoretical basis for understanding, analyzing, designing, and improving operations. After completing this course:

1. Students can conduct basic process mapping analysis and elaborate on the limitations of the chosen method.
2. Students can calculate the needed capacity to meet demand.
3. Students can select and use problem-solving tools and methods.
4. Students can select and use the basic tools of lean thinking to improve the productivity of production and service operations.
5. Students can explain how new technologies and servitization affect production and operations management.
6. Students can calculate the needed capacity to meet demand.
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

**Objective**

**Content**
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM). POM is concerned with business processes that transform input into output and deliver products and services to customers. POM is more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota, to mention a few (although factory management is important and a big part of POM). Also, finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitalization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance measurement. (3) Operations improvement, including problem-solving and the use of new technologies in POM ("Industry 4.0" / digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

**Literature**
Suggested literature is provided in the syllabus.

<table>
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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0445-02L</td>
<td>Production and Operations Management – Supplement Credit</td>
<td>W</td>
<td>1</td>
<td>1A</td>
<td>T. Netland</td>
</tr>
</tbody>
</table>

**Abstract**
A parallel enrolment to the lecture 363-0445-00L Production and Operations Management is mandatory.

**Objective**
This course strengthens the learning objectives of the POM core course (see separate syllabus). After completing this course, students can:

1. Students can conduct basic process mapping analyses.
2. Students can select and implement many lean production techniques.
3. Students can conduct basic process mapping analyses and elaborate on the limitations of the chosen method.
4. Students can calculate the needed capacity to meet demand.
5. Students can select and use problem-solving tools and methods, and students understand the role of management in manufacturing.
6. Students can conduct fundamental process mapping analyses.
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

**Content**
The course is an extension to the course 363-0445-00 Production and Operations Management. Participants get an extra deep dive into key concepts of POM.

The lectures in this course are highly interactive. To pass this course, students need to complete a course assignment in pairs. The course assignment consists of two parts: preparations for the lecture and a reflection essay after the lecture.

**Prerequisites / notice**
This course (1ECTS) is offered as an extension to the D-MTEC core course 363-0445-02 Production and Operations Management (3 ECTS). To take this course, you have to follow the core course.

Due to its practical format, this course is limited to a maximum of 30 students. Note that we offer this course primarily for students who need the extra credit (total of 4 ECTS) to complete their study plans. This will typically be students from D-MAVT and, in some cases, exchange students. Students from all other departments (inducing D-MTEC) are welcome to apply to the lecturer. If capacity, applicants may receive written acceptance by the team to join.

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<tbody>
<tr>
<td>101-0491-00L</td>
<td>Agent Based Modeling in Transportation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Balac</td>
</tr>
</tbody>
</table>

**Abstract**
This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.

**Objective**
At the end of the course, the students should:
1. have an understanding of agent-based modeling
2. have an understanding of MATSim
3. have an understanding of the process needed to set up an agent-based study
4. have practical experience of using MATSim to perform practical transportation studies
Content
This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1) Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2) Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3) Setting up an agent-based model and the event of accident, presenting possibilities to increase road safety
4) Conducting a transport policy study. The course will be presented from beginning to end.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).

Literature
Agent-based modeling in general

MATSim

Prerequisites / notice
There are no strict preconditions in terms of which lectures the students should have previously attended. However, knowledge of basic mathematical optimization techniques is expected, and experience with at least one high-level programming language (Java, Python, or other) is recommended.

101-0492-00L Microscopic Modelling and Simulation of Traffic Operations

Abstract
The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

Objective
The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Literature

Further literature: will be presented during the course.

401-0647-00L Introduction to Mathematical Optimization

Abstract
Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering. The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.
Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

This course is meant for students who did not already attend the course "Mathematical Optimization", which is a more advance lecture covering similar topics. Compared to "Mathematical Optimization", this course has a stronger focus on modeling and applications.

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<tr>
<th>Number</th>
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<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0258-00L</td>
<td>River Engineering</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Weitbrecht, I. Schalko, K. Sperger</td>
</tr>
<tr>
<td>101-0469-00L</td>
<td>Road Safety</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Deubel, P. Eberling</td>
</tr>
<tr>
<td>101-0492-00L</td>
<td>Microscopic Modelling and Simulation Traffic Operations</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Makridis</td>
</tr>
</tbody>
</table>

Abstract

The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective

At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

Content

The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

Lecture notes

Handouts and powerpoint presentations shown in the lecture can be downloaded via Moodle.

Literature

1. Flussbau-lecure notes of fall semester 2020 by Dr. Gian Reto Bezzola (available only in German at VAW teaching assistance)
2. Erosion and Sedimentation; Pierre Y. Julien
3. River Mechanics; Pierre Y. Julien

Recommended lectures:
- Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Prerequisites / notice

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

Abstract

The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety Aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.

Objective

Imparting knowledge base about road safety and the event of accident, presenting possibilities to increase road safety

Content

Accident origin, collection of road accidents, statistical (descriptive and multivariate, accident prediction models) and geographical analysis of road accidents, risk analysis and rehabilitation measures, road safety instruments for infrastructure with focus on road safety audit, Swiss and international transport policy

Literature


Further literature: will be presented during the course

Abstract

The course introduces basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies.

The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.

Objective

The objective of this course is to conduct a realistic traffic engineering project from beginning to end. The students will first familiarize themselves with microscopic traffic models. Students will work in groups on a project that includes a base scenario on a real traffic network. Throughout the semester, along with theoretical concepts, the students will build the base scenario (design, calibration and validation) and will develop alternative scenarios regarding modification on the infrastructure, simulation of in-vehicle technologies and vehicle-to-everything (V2X) communication.

Simulations will be implemented in Airsfn software. The students will be asked to understand, analyze, interpret and present traffic properties. Evaluation of alternative scenarios over the same network will be performed. Finally, students will be asked to design, implement, analyze and present a novel proposal, which will be compared with the base scenario.

Upon completion of the course, the students will:
- Understand the basic models used in microsimulation software (car-following, lane changing, gap acceptance, give ways, on/off-ramps, etc.)
- Design a road transport network inside the simulation software.
- Understand the basics behind modeling traffic demand and supply, vehicle dynamics, performance indicators for evaluation and network design for a realistic road transport network.
- Understand how to design a complete study, implement and validate it for planning purposes, e.g. creating a new road infrastructure.
- Make valid and concrete engineering proposals based on the simulation model and alternative scenarios.
In this course, the students will first learn some microscopic modelling and simulation concepts, and then complete a traffic-engineering project with microscopic traffic simulator Aimsun. Microscopic modelling and simulation concepts will include:

1) Car following models
2) Lane change models
3) Calibration and validation methodology

Specific tasks for the project will include:

1) Building a model with the simulator Aimsun in order to replicate and analyze the traffic conditions measured/observed.
2) Calibrating and validating the simulation model.
3) Redesigning/extending the model to improve the traffic performance through Aimsun and without programming in Python or C++.

The course will be based on a project that each group of students will build (design, calibrate, analyze and presentation) across the semester. A mid-term and final presentation of the work will be asked from each group of students. It consists of weekly 2-hour lectures. The students work in pairs on a project that completes in the end of the semester. The modelling software used is Aimsun and lectures (theory and hands on experience) are taking place in a computer room. The course Road Transport Systems (Verkehr III), or simultaneously taking the course Traffic Engineering is encouraged. Previous experience with Aimsun/Python/C++ is helpful but not mandatory.

The course Traffic Engineering is encouraged. Previous experience with Aimsun is helpful but not mandatory.

The lecture notes and additional handouts will be provided before the lectures. Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Additional literature recommendations will be provided at the lectures.

101-0419-02L Railway Infrastructures 2  W  2 credits  2G  U. A. Weidmann, P. Gültenapfel, M. Kohler, M. J. Manhart

Abstract
Track geometry including calculation and measuring as well as related data systems; clearance profiles; interaction between track and vehicles, vehicle dynamics, stress; track construction including special features of railway bridges and tunnels; environmental aspects in track construction; track diagnostics and forecast; track maintenance and related methods

Objective
The lecture gives a deeper insight into track geometry including clearance profile, the interaction between track and vehicles as well as in construction and dimensioning of the track. Methods for the diagnosis of the state of the track and its forecast are shown. State-of-the-art maintenance strategies and technologies are presented.

Content
1 - Track geometry
Track geometry including calculation and measuring as well as related data systems; clearance profiles
2 - Interaction
Interaction between track and vehicles, vehicle dynamics
3 - Railway Track
Stress; track construction including special features of railway bridges and tunnels
4 - Environmental aspects in track construction
Fundamentals; noise protection; vibration protection
5 - Diagnostics, maintenance strategies
Track diagnostics and forecast; maintenance strategies
6 - Track maintenance
Fundamentals of track maintenance and related methods

Lecture notes
The slides will be made available.


Literature
A list with related technical literature will be handed out.

Prerequisites / notice
Prerequisite: 101-0419-01 Railway Infrastructures 1 (FS)

101-0187-00L Structural Reliability and Risk Analysis  W  3 credits  2G  S. Marelli

Abstract
Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modelling and computational methods for reliability and risk assessment.

Objective
The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Content
Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro- codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post and pre-post risk assessment methods are presented.

Lecture notes
Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.

Literature
S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.

Prerequisites / notice
Basic course on probability theory and statistics

H H H Major Courses for all Majors

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0507-00L</td>
<td>Infrastructure Management 3: Optimisation Tools</td>
<td>W</td>
<td>6</td>
<td>2G</td>
<td>B. T. Adey</td>
</tr>
</tbody>
</table>

Abstract
This course will provide an introduction to the methods and tools that can be used to determine optimal inspection and intervention strategies and work programs for infrastructure.

Objective
Upon successful completion of this course students will be able:
- to use preventive maintenance models, such as block replacement, periodic preventive maintenance with minimal repair, and preventive maintenance based on parameter control, to determine when, where and what should be done to maintain infrastructure
- to take into consideration future uncertainties in appropriate ways when devising and evaluating monitoring and management strategies for physical infrastructure
- to use operation research methods to find optimal solutions to infrastructure management problems

Content
Part 1:
Explanation of the principal models of preventative maintenance, including block replacement, periodic group repair, periodic maintenance with minimal repair and age replacement, and when they can be used to determine optimal intervention strategies

Part 2:
Explanation of preventive maintenance models that are based on parameter control, including Markovian models and opportunistic replacement models

Part 3:
Explanation of the methods that can be used to take into consideration the future uncertainties in the evaluation of monitoring strategies

Part 4:
Explanation of how operations research methods can be used to solve typical infrastructure management problems

Lecture notes
A script will be given out at the beginning of the course.
Class relevant materials will be distributed electronically before the start of class.
A copy of the slides will be handed out at the beginning of each class.

Prerequisites / notice
Successful completion of IM1: 101-0579-00 Evaluation tools is a prerequisite for this course.

H H H Interdisciplinary Project Work

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0489-02L</td>
<td>Interdisciplinary Project</td>
<td>O</td>
<td>12</td>
<td>26A</td>
<td>A. Grêt-Regamey</td>
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Abstract
The Interdisciplinary Project Activity (IPA) forms the key feature of the MSc RE&IS. Students work on an interdisciplinary task from the field of spatial development and infrastructure systems in a real application area. The focus of the IPA on interdisciplinary cooperation and strong communication skills are crucial expertise required in practice to communicate with and between relevant actors.

Objective
Upon completion of the IPA, students have developed skills in:

1) Investigating and understanding a given project area in a real-world context as well as identifying, evaluating and formulating the current issues and relevant topics within that area.

2) Creating, designing/developing and evaluating an overall integrated strategy for the project area with relevant measures as well as an in-depth study of a certain area or topic within the project area visualizing, describing, presenting and reporting on these in a written project report.

3) Organising, structuring and promoting team work within an interdisciplinary group of 4-5 students in self-responsibility.

4) Applying previously learnt interdisciplinary methodological and theoretical skills from different fields as well as methods and design thinking learnt during the IPA.

5) Evaluating and choosing the right way of representation (e.g.: text, statistics, images, etc.) for all pieces of information, ideas and proposals throughout the whole semester.

6) Understanding, developing and strengthening and critically self-evaluating their individual disciplinary position and role.
Students apply the full range of their previously learned theoretical and methodological skills to solve the task together in their project team. Working closely with representatives of the case study area (e.g. officials, the wider public, different experts and decision-makers), which changes annually, as well as other experts, through site visits, and through individual mentoring by the six RE&IS chairs, students work in a stimulating and motivating environment to solve real-world spatial challenges.

- The semester is structured through an intermediate and final presentation, bilateral discussions with the chairs involved as well as individual group mentoring. On these meetings, the work status has to be communicated with adequate representational means and is discussed with the professors, assistants and possibly external experts.

- The project begins with a site visit of the project area at the beginning of the semester and the identification as well as precise formulation of the issues and opportunities observed within the project area.

- The students work on a complex, rather rough task and define their exact objective independently on the basis of the as-is analysis. In the overall strategy, the future development direction for the project area is then determined and measures are formulated to steer the development in this direction. Within a focus area or focus topic, students further develop their project and deepen their overall strategy. They test and evaluate the impact of selected measures and finally reflect on their project, summarize the most important findings and make a recommendation formulated to decision-makers.

- The project gets developed in an interdisciplinary group of students. The internal structuring of the group and distribution of work is to be organised by the students themselves.

- The choice of software for the project development is up to the students. The software used should be applicable to data analysis, information processing, image production and word processing. This can include the Adobe programs such as InDesign, Illustrator or Photoshop, GIS, the Microsoft programs such as Word, PowerPoint or Excel, CAD, R, etc.)

### Taught competencies

#### Domain A - Subject-specific Competencies

- Concepts and Theories assessed
- Techniques and Technologies assessed

#### Domain B - Method-specific Competencies

- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

#### Domain C - Social Competencies

- Communication assessed
- Cooperation and Teamwork assessed
- Customer Orientation not assessed
- Leadership and Responsibility assessed
- Self-presentation and Social Influence assessed
- Sensitivity to Diversity not assessed
- Negotiation assessed

#### Domain D - Personal Competencies

- Adaptability and Flexibility assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection assessed
- Self-direction and Self-management assessed

### Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>103-0010-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>24 credits</td>
<td>51D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 16 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

**Objective**

To work independently and to produce a scientifically structured work.

**Content**

The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

### Electives

The entire course programs of ETH Zurich and University Zurich are open to the students to individual selection. The students have themselves to check whether they meet the admission requirements for a course.

### Recommended Electives of Master Degree Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>103-0227-00L</td>
<td>Cartography III</td>
<td>W</td>
<td>5 credits</td>
<td>4G</td>
<td>L. Hurni</td>
</tr>
</tbody>
</table>

**Abstract**

This follow-up course proceeds to a complete Web map project and introduces in 3D and animated cartography.

**Objective**

This course enables students to plan, design and realize interactive Web map projects. The introduction to 3D and animated cartography also provides a general knowledge about animated 3D graphics.
### Systemic Design Labs: RE:GENERATE Alpine-Urban

**Content**
- Design Challenge: How to re-design alpine-urban circularity? How to revive mountain livelihoods, focusing on local identity, resilient landscapes and a regenerative economy? What is a regenerative relation between the alpine and the urban? Covid has accelerated and intensified a traditionally challenging relation of the alpine (mountain livelihoods) and the urban. Both depend on each other, but there are as well many unsustainable elements in this relation, especially for the alpine.
- The specific design challenge is to identify and layout a holistic, partly quantified and visualized systems strategy for building a resilient community economy in relation to the actual Covid driven pressure factors in the relation of the alpine with the urban. We build upon former ETH SDL students who developed a systems maps for the community of Ostanza, Italy, that embraces local identity, revitalizes cultural and landscape biodiversity, and creates alpine-urban circularity.
- This course will extend this systems map to more clearly understand the urban component, the source market, and design in new opportunities of urban-alpine regeneration, for circularity, for new ways of tourism, of mobility, in a creative economy.
- Recap of former SDL courses:
  - In Ostanza, a clear connection is between the local identity (culture, traditions, visions) which is formed by Occitan culture (food, music, dance, language), traditional stone building architecture which is under pressure to carefully evolve with new needs for carbon-neutral and net-positive buildings, and the Monte Viso landscape. How does a re-growing economy that should be regenerative and circular by design, correlate with innovation in architecture, with population growth and associated challenges in mobility, waste systems and supplies, with growing tourism, new agro-forestry practices like industrial hemp and Paulownia, while impacts of climate change are clearly visible? How does the community design a vision that is based on cooperation on different governance scales, balancing local identity and urgently needed international innovation?

**Deliverables & output:** This SDL course RE:GENERATE builds upon related work from former courses hosted and lead by the MonViso Institute (i.e. on social innovation, mobility, architecture and local identity, tourism, circular economy, land use change) to develop and design foundational for an extension of the existing systems map, that will support ongoing and future innovation processes in this community. The focus now is on the urban integration into new, regenerative business models of the alpine, and in regenerative relation between both as a model for the future. This course will thus develop an extended graphical systems map from the alpine to the urban, backed up by a technical report, and connected with the existing systems maps of Ostanza and the surrounding valley.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Start</th>
<th>End</th>
<th>Lecturer</th>
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<tbody>
<tr>
<td>101-0193-00L</td>
<td>Systemic Design Labs: RE:GENERATE Alpine-Urban</td>
<td>4</td>
<td>Autumn Semester 2021</td>
<td></td>
<td>T. Luthe</td>
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<tr>
<td>151-0757-00L</td>
<td>Environmental Management</td>
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<td>R. Züst</td>
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<tr>
<td>851-0703-03L</td>
<td>Private Construction Law</td>
<td>2</td>
<td></td>
<td>T. Ender, E. Ruegg</td>
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</tr>
</tbody>
</table>
Upon successful completion of this course students will be able:

- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving

Communication
- Project Management
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Prerequisites / notice

Depending on the Covid situation, some part of the course will be virtual via Zoom, using a Miro design board. If possible, we will do a field trip. Some travel costs may apply.

Students need to be motivated to design in teams on the preparation of the deliverables, a systemic strategy map and a written report.

Prerequisites / Literature


- Modelling with mathematical optimization: applications of mathematical programming in engineering.
- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).
- Linear programming (simplex method, duality theory, shadow prices, ...).
- Modelling with mathematical optimization: applications of mathematical programming in engineering.
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

Handouts and powerpoint presentations shown in the lecture can be downloaded via Moodle.

Suggested literature is provided in the syllabus.

1. «Flussbau» lecture notes of fall semester 2020 by Dr. Gian Reto Bezzola (available only in German at VAW teaching assistance)
2. Erosion and Sedimentation; Pierre Y. Julien
3. River Mechanics; Pierre Y. Julien

Recommended lectures:
Hydrology (102-0293-AAL), Hydraulics I (101-0203-01L), and Hydraulic Engineering (101-0206-00L).

Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

**Abstract**
This core course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.

**Objective**
This course provides students a broad theoretical basis for understanding, analyzing, designing, and improving operations. After completing this course:

1. Students can apply key concepts of POM to detail an operations strategy,
2. Students can conduct basic process mapping analysis and elaborate on the limitations of the chosen method,
3. Students can calculate the needed capacity to meet demand,
4. Students can select and use problem-solving tools and methods,
5. Students can calculate the basic tools of lean thinking to improve the productivity of production and service operations,
6. Students can explain how new technologies and servitization affect production and operations management,
7. Additional skills: Students acquire experience in teamwork, report writing, and presentation.

**Content**
The course covers the most fundamental strategic and tactical concepts in production and operations management (POM).

POM is concerned with the business processes that transform input into output and deliver products and services to customers. POM is much more than what takes place inside the production facilities of companies like ABB, Boeing, BMW, LEGO, Nestlé, Roche, TESLA, and Toyota, to mention a few (although factory management is important and a big part of POM). Also, finance firms, professional service firms, media organizations, non-profit organizations, and public service companies are dependent on their operational capabilities. With the ongoing globalization and digitization of operations, POM has won a deserved status for providing a competitive advantage.

The following three fundamental areas in POM are covered: (1) Introduction to POM and operations strategy. (2) Operations design and management, including demand and capacity management, production planning and control, the role of inventory, lean management, service operations, and performance measurement. (3) Operations improvement, including problem-solving and the use of new technologies in POM (“Industry 4.0” / digitalization). Students can expect to learn a range of useful concepts, principles, and methods that can be used to design, analyze, and improve value-creating processes.

POM is concerned with the productivity of technology, people, and processes. Hence, POM is a generic research field, relevant to all business sectors. Yet, many of the examples and concepts of POM stem from the manufacturing sector, which for many years have been subject to global competition and learned how to develop effective and efficient operations.

**Literature**
Suggested literature is provided in the syllabus.

**363-0445-00L Production and Operations Management**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Abstract</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 3 credits</td>
<td>This course provides insights into the basic theories, principles, concepts, and techniques used to design, analyze, and improve the operational capabilities of an organization.</td>
<td>701-0565-00L Fundamentals of Natural Hazards Management</td>
</tr>
</tbody>
</table>

**Abstract**

Risks to life and human assets result when settlement areas and infrastructure overlap regions where natural hazard processes occur. This course utilizes case studies to teach how a future natural hazards-specialist should analyze, assess and manage risks.

**Objective**

Concepts will be explained step-by-step through a set of case studies, and applied in lab by the students. The following principal steps are used when coping with natural hazard-risks. At each step, students will learn and apply the following skills:

- Risk analysis - What can happen?
- Risk assessment - What are the acceptable levels of risk?
- Identify threats to human life and assets exposed to natural hazards and estimate possible drawbacks or damages.
- Risk management - What steps should be taken to manage risks?
- Apply principles to determine acceptable risks to human life and assets in order to identify locations which should receive added protection.
- Explain causes for conflicts between risk perception and risk analysis.
- Explain how various hazard mitigation approaches reduce risk.
- Describe hazard scenarios as a base for adequate dimensioning of control measures.
- Identify the best alternative from a set of thinkable measures based on an evaluation scheme.
- Explain the principles of risk-governance.
This course focuses on the history of the design of cities, as well as on the ideas, processes and actors that engender and lead their development and transformation. The history of urban design will be approached as a cross-cultural field of knowledge that integrates scientific, economic and technical innovation as well as social and cultural advances.

The lectures deal mainly with the definition of urban design as an independent discipline, which maintains connections with other disciplines (politics, sociology, geography) that are concerned with the transformation of the city. The aim is to make students conversant with the multiple theories, concepts and approaches of urban design as they were articulated throughout time in a variety of cultural contexts, thus offering a theoretical framework for students' future design work.

In the first semester the genesis of the objects of study, the city, urban culture and urban design, are introduced and situated within their intellectual, cultural and political contexts:

1. The History and Theory of the City as Project
2. Of Rituals, Water and Mud: The Urban Revolution in Mesopotamia and the Indus
3. The Idea of the Polis: Rome, Greece and Beyond
4. The Long Middle Ages and their Counterparts: From the Towns of Tuscany to Delhi
5. Between Ideal and Laboratory: Of Middle Eastern Grids and European Renaissance Principles
6. Of Absolutism and Enlightenment: Baroque, Defense and Colonization
7. The City of Labor: Company Towns as Cross-Cultural Phenomenon
8. Garden Cities of Tomorrow: From the Global North to the Global South and Back Again
9. Civilized Wilderness and City Beautiful: The Park Movement of Olmsted and The Urban Plans of Burnham
10. The Extension of the European City: From the Viennese Ringstrasse to Amsterdam Zuid

Prior to each lecture a chapter of the reader (Skript) will be made available through the webpage of the Chair. These chapters will provide an introduction to the lecture, the basic visual references of each lecture, key dates and events, as well as references to the compulsory and additional reading.

These books will be reserved for consultation in the ETH Baubibliothek, and will not be available for individual loans.

A list of further recommended literature will be found within each chapter of the reader (Skript).

Structural reliability aims at quantifying the probability of failure of systems due to uncertainties in their design, manufacturing and environmental conditions. Risk analysis combines this information with the consequences of failure in view of optimal decision making. The course presents the underlying probabilistic modeling and computational methods for reliability and risk assessment.

The goal of this course is to provide the students with a thorough understanding of the key concepts behind structural reliability and risk analysis. After this course the students will have refreshed their knowledge of probability theory and statistics to model uncertainties in view of engineering applications. They will be able to analyze the reliability of a structure and to use risk assessment methods for decision making under uncertain conditions. They will be aware of the state-of-the-art computational methods and software in this field.

Engineers are confronted every day to decision making under limited amount of information and uncertain conditions. When designing new structures and systems, the design codes such as SIA or Euro-codes usually provide a framework that guarantees safety and reliability. However the level of safety is not quantified explicitly, which does not allow the analyst to properly choose between design variants and evaluate a total cost in case of failure. In contrast, the framework of risk analysis allows one to incorporate the uncertainty in decision making.

The first part of the course is a reminder on probability theory that is used as a main tool for reliability and risk analysis. Classical concepts such as random variables and vectors, dependence and correlation are recalled. Basic statistical inference methods used for building a probabilistic model from the available data, e.g. the maximum likelihood method, are presented.

The second part is related to structural reliability analysis, i.e. methods that allow one to compute probabilities of failure of a given system with respect to prescribed criteria. The framework of reliability analysis is first set up. Reliability indices are introduced together with the first order-second moment method (FOSM) and the first order reliability method (FORM). Methods based on Monte Carlo simulation are then reviewed and illustrated through various examples. By-products of reliability analysis such as sensitivity measures and partial safety coefficients are derived and their links to structural design codes is shown. The reliability of structural systems is also introduced as well as the methods used to reassess existing structures based on new information.

The third part of the course addresses risk assessment methods. Techniques for the identification of hazard scenarios and their representation by fault trees and event trees are described. Risk is defined with respect to the concept of expected utility in the framework of decision making. Elements of Bayesian decision making, i.e. pre-, post- and pre-post risk assessment methods are presented.

The course also includes a tutorial using the UQLab software dedicated to real world structural reliability analysis.

Slides of the lectures are available online every week. A printed version of the full set of slides is proposed to the students at the beginning of the semester.


S. Marelli, R. Schöbi, B. Sudret, UQLab user manual - Structural reliability (rare events estimation), Report UQLab-V0.92-107.
This course examines the behaviour of macroeconomic variables, such as gross domestic product, unemployment and inflation rates. It tries to answer questions like: How can we explain fluctuations of national economic activity? What can economic policy do against unemployment and inflation?

This lecture will introduce the fundamentals of macroeconomic theory and explain their relevance to every-day economic problems. As a voter, you help choose the policies that guide the allocation of society's resources. When deciding which policies to support, you may find yourself asking various questions about economics. What are the burdens associated with alternative forms of taxation? What are the effects of free trade with other countries? How does the government budget deficit affect the economy? These and similar questions are always on the minds of policy makers.

This book can also be used for the course '363-0503-00L Principles of Microeconomics' (Filippini).

Besides this textbook, the slides, lecture notes and problem sets will cover the content of the lecture and the exam questions.

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Urban Design III

Students are introduced to a narrative of 'Urban Stories' through a series of three tools driven by social, governance, and environmental transformations in today's urbanization processes. Each lecture explores one city's spatial and organizational ingenuity born out of a particular place's realities, allowing students to transfer these inventions into a catalog of conceptual tools.

How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how. We look at the people, institutions, culture behind the design and make concepts behind these tools visible. Students get first-hand information from cities where the chair as a Team has researched, worked, or constructed projects over the last year, allowing competent, practical insight about the people and topics that make these places unique. Students will be able to use and expand an alternative repertoire of experiences and evidence-based design tools, go to the conceptual core of them, and understand how and to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.

Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-coordinated processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reference.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.
Production and Operations Management – Adaptability and Flexibility

L. Meier

Extension to course 363-0445-00 Production and Operations Management. Key topics include:

- Students use lean thinking to improve productivity of production processes,
- Students conduct fundamental process mapping analyses,
- Students select and implement lean production techniques,
- Students select and use problem-solving tools and methods, and
- Students understand the role of management in manufacturing.

Course content includes:

- Equivalence between optimization and separation.
- Combinatorial optimization problems and polyhedral techniques;
- Linear programming and polyhedra;
- Flow and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Prerequisites / notice

This course (1ECTS) is offered as an extension to the D-MTEC core course 363-0445-02 Production and Operations Management (3 ECTS). To take this course, you have to follow the core course.

Due to its practical format, this course is limited to ca 30 students. Note that we offer this course primarily for students who need the extra credit (total of 4 ECTS) to complete their study plans. This will typically be students from D-MAVT and, in some cases, exchange students. Students from all other departments (inducing D-MTEC) are welcome to apply to the lecturer. If capacity, applicants may receive written acceptance by the teaching team to join.
Different selected topics in hydraulic engineering will be focused on, e.g. dam safety, materials in dam building, possible problems at reservoirs like natural hazards by impulse waves, the hydraulics of spillways and intake structures at dams and weirs and the area of conflict between hydropower and ecology. Another focus will be put on typical approaches and procedures in the planning process of hydropower projects at the national and international level.

**Lecture notes**
Lecture notes will be available online.

**Prerequisites / notice**
External speakers will be involved to present current topics and projects in Switzerland and abroad.

### Electives ETH Zurich

**Course Catalogue of ETH Zurich**

#### GESS Science in Perspective

- see GESS Science in Perspective: Language Courses
- ETH/UZH

- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

- Recommended GESS Science in Perspective (Type B) for D-BAUG.

#### Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0031-AAL</td>
<td>Systems Engineering</td>
<td>E-</td>
<td>4</td>
<td>9R</td>
<td>B. T. Adey</td>
</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

**Abstract**
- Systems Engineering is a way of thinking that helps engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms.
- This course provides an overview of the main principles of Systems Engineering, and includes an introduction to the use of operations research methods in the determination of optimal systems.

**Objective**

The world's growing population, changing demographics, and changing climate pose formidable challenges to humanity's ability to live sustainably. Ensuring that humanity can live sustainably requires accommodating Earth's growing and changing population through the provision and operation of a sustainable and resilient built environment. This requires ensuring excellent decision-making as to how the built environment is constructed and modified.

The objective of this course is to ensure the best possible decision making when engineering sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long term. In this course, you will learn the main principles of Systems Engineering that can help you from the first idea that a system may not meet expectations, to the quantitative and qualitative evaluation of possible system modifications. Additionally, the course includes an introduction to the use of operations research methods in the determination of optimal solutions in complex systems.

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.
The weekly content is structured as follows:

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. An introduction to the example that we will be working with through most of the course. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. Analysis – 1/5 – The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, display, weighting, and expected value.
6. Analysis – 2/5 – The idea behind the supply and demand curves and revealed preference methods.
7. Analysis – 3/5 – The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. Analysis – 4/5 – The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Marginal rates of return and internal rates of return.
9. Analysis – 5/5 – How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Evaluation of solutions – Regardless how sophisticated an analysis is, it requires that decision makers stand back and critically evaluate the results. This week we discuss the aspects of evaluating the results of an analysis.
11. Operations research – 1/4 – Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. This week we discuss linear programming and the simplex method.
13. Operations research – 3/4 – How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
14. Operations research – 4/4 – How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches. The quantitative analyses requires the use of Excel. An introduction to Excel will be provided in one of the help sessions.

The script for the original course is in German. The English material that can be used for the virtual course is:


The literature will be made available at the beginning of the course.

### Literature

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
|                                           | Decision-making | assessed |
|                                           | Media and Digital Technologies | not assessed |
|                                           | Problem-solving | assessed |
| Domain C - Social Competencies | Communication | not assessed |
|                                           | Cooperation and Teamwork | not assessed |
|                                           | Customer Orientation | not assessed |
|                                           | Leadership and Responsibility | not assessed |
|                                           | Self-presentation and Social Influence | not assessed |
|                                           | Sensitivity to Diversity | not assessed |
|                                           | Negotiation | not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | not assessed |
|                                           | Creative Thinking | not assessed |
|                                           | Critical Thinking | assessed |
|                                           | Integrity and Work Ethics | not assessed |
|                                           | Self-awareness and Self-reflection | not assessed |
|                                           | Self-direction and Self-management | not assessed |

### Taught competencies

<table>
<thead>
<tr>
<th>101-0414-AAL</th>
<th>Transport Planning (Transportation I)</th>
<th>E- 3 credits 6R K. W. Axhausen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
<td></td>
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</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract

The lecture course discusses the basic concepts, approaches and methods of transport planning in both their theoretical and practical contexts.

### Objective

The course introduces the basic theories and methods of transport planning.

### Content

Basic theoretical links between transport, space and economic development; basic terminology; measurement and observation of travel behaviour; methods of the four stage approach; cost-benefit analysis.

### Literature


<table>
<thead>
<tr>
<th>101-0515-AAL</th>
<th>Project Management</th>
<th>E- 2 credits 4R B. T. Adey</th>
</tr>
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<tbody>
<tr>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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</tr>
</tbody>
</table>

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

### Abstract

General introduction to the development, the life cycle and the characteristics of projects. Introduction to, and experience with, the methods and tools to help with the preparation, evaluation, organisation, planning, controlling and completion of projects.

### Objective

To introduce the methods and tools of project management. To impart knowledge in the areas of project organisation and structure, project planning, resource management, project controlling and on team leadership and team work.
Content
- From strategic planning to implementation (Project phases, goals, constraints, and feasibility)
- Project leadership (Leadership, Teams)
- Project organization (Structure)
- Project planning (Schedule, cost and resource planning)
- Project controlling
- Risk and Quality Management
- Project completion

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain D - Personal Competencies
- Critical Thinking

102-0516-AAL Environmental Impact Assessment
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Focus of the course are the method, the process and content of the Environmental Impact Assessment (EIA) as well as the legal bases and methods for compiling an environmental impact study (EIS).
Excurions provide a comprehensive view of the EIA.
Using exemplary projects, the process of an EIA will be worked out by the students.

Objective
- Understanding the context of spatial planning and environmental protection
- Ability to use central planning instruments and procedures for assessing the environmental impacts and risks of projects
- Ability to apply quantitative methods to assess the environmental impacts and risks of projects
- Knowledge about the process and content of an EIA
- a capacity for critical review of environmental impact assessments

Content
- Nominal and functional environmental protection in Switzerland
- Instruments of environmental protection
- Need for coordination between environmental protection and spatial planning
- Environmental Protection and environmental impact assessment
- Legal basis of the EIA
- Procedure of EIA
- Content of the EIA
- Application of the impact analysis
- Monitoring and Controlling
- View regarding the strategic environmental assessment (SEA)
- Excursions to projects obligated under the EIA

Lecture notes
No script. The documents for the lecture can be found for download on the homepage of the Chair of Planning of Landscape and Urban Systems.

Literature
Supplementary literature is available for download on the homepage of the Chair of Planning of Landscape and Urban Systems.

103-0116-AAL Ecology and Soil Science
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
The main focus of the lecture are the basics of ecology and soil science. Students learn about the interdependence of organisms and environment, resource cycles, ecosystems as well as soil characteristics and genesis. The impact of human behavior on ecosystems and the problems of different land use are covered by the lecture, too.

Objective
- getting insights into the basics of ecology
- ability to assess the consequences of spatial planning on ecosystems
- understanding of ecological processes and interdependency
- understanding of function and potential of soil

Content
Basics of Ecology
- definition of ecology, types, habitat, ecosystem, environment
- human influence on ecosystem
- context of landscape and ecology
- ecological context for practical application (e.g. in spatial planning)

Basics of Soil Science
- basic concept and definition of soil, soiltype and essential parameters
- soil water balance (irrigation, drainage)
- soil compaction and erosion
- reclamation and renaturation
- material pollution of soil and remediation approaches
- soil and spatial planning

Lecture notes
Lecture notes and slides (in German) can be downloaded from the PLUS homepage.

Literature
Lecture notes and slides (in German) can be downloaded from the PLUS homepage.

103-0313-AAL Spatial Planning and Landscape Development
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
The lecture introduces into the main-features of spatial planning. Attended will be the subjects of planning as a national responsibility, instruments of spatial planning, techniques for problem solving in spatial planning and the Swiss concept for regional planning.

Objective
- To get to know the interaction between the community and our living space and their resulting conflicts.
- Link theory and practice in spatial planning.
- To get to know instruments and facilities to process problems in spatial planning.
Environmental Planning

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The lecture covers tools, methods and procedures of Landscape and Environmental Planning developed. By means of field trips their implementation will be illustrated.

Objective
Knowledge of the various instruments and possibilities for the practical implementation of environmental planning. Knowledge of the complex interactions of the instruments.

Content
Topics of the Lectures
- forest planning
- inventories
- intervention and compensation
- ecological network
- agricultural policy
- landscape development concepts (LEK)
- parks
- swiss landscape concept
- riverine zone
- natural hazards

Note: there are several non-obligatory field trips as part of the lecture. It is recommended to participate at these to boost the in-depth understanding of the different topics.

Lecture notes
- lecture notes concerning the instruments
- handouts
- copies of selected literature

Download: http://www.plus.ethz.ch/de/studium/vorlesungen/bsc/environmental_planning.html

Transport Basics

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
- Introduction to the fundamentals of transportation
- Developing an understanding of the interactions between land use and transportation
- Introduction to the dynamics of transport systems: daily patterns and historical developments

Content
- Accessibility
- Equilibrium in transport networks
- Fundamental transport models
- Traffic flow and control
- Vehicle dynamics on road and rail
- Transport modes and supply patterns
- Time tables

Computer Science II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
The students will be able to write simple programs and to modify existing programs.

Content
This course offers an introduction to variables, control structures (branch, loop), algorithms and data structures, as well as an outlook to modularisation and object oriented techniques.

In the exercises students train programming skills (in the programming language JAVA). Students can solve the exercises on their own laptop or in the computer labs at ETH. The software used in this course runs on MS Windows, MacOS X and Linux.

Prerequisites / notice
Prerequisites:
252-0845-00 Computer Science I (D-BAUG)

Analysis II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to programming in Java. Procedural foundations of programming and outlook to object oriented programming. Variables, types, assignments, control structures (branch, loop), data structures, algorithms, line graphics, graphical user interface. Writing small programs.

Objective
Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineer.

Content

Literature
Textbooks in English:
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus
- M. Akveld, R. Sperb, Analysis II, vdf
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag

Mathematics I

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineer.

Objective

Literature
Textbooks in English:
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus
- M. Akveld, R. Sperb, Analysis II, vdf
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Objective
Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.

Content
1. Linear Algebra and Complex Numbers:
   systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.

2. Single-Variable Calculus:
   review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

3. Ordinary Differential Equations:
   separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

Literature
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).

Prerequisites / notice
Prerequisites: familiarity with the basic notions from Calculus, in particular those of function and derivative.

Assistance:
Tuesdays and Wednesdays 17-19h, in Room HG E 41.
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract

Objective
Primäres Lernziel der Vorlesung ist die Befähigung zum Programmieren mit C++. Studenten beherrschen nach erfolgreichem Abschluss der Vorlesung die Mechanismen zum Erstellen eines Programms, sie kennen die fundamentalen Kontrollstrukturen, Datenstrukturen und verstehen, wie man ein algorithmisches Problem in ein Programm abbildet. Sie haben eine Vorstellung davon, was "hinter den Kulissen" passiert, wenn ein Programm übersetzt und ausgeführt wird.

Content

Lecture notes
Ein Skript in englischer Sprache wird semesterbegleitend herausgegeben. Das Skript und die Folien werden auf der Vorlesungshomepage zum Herunterladen bereitgestellt.

Literature
Bjarne Stroustrup: Einführung in die Programmierung mit C++, Pearson Studium, 2010

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Advanced geoinformation technologies and analyses methods: Mobile GIS; Web-GIS & Geo-Web-Services; Spatial Big Data; Temporal aspects in GIS; Analysis of movement data; User interfaces

Objective
Knowing advanced topics of geoinformation technologies (Mobile GIS and Web-GIS) and spatio-temporal analysis methods for the realization, application and operation of Web-GIS in engineering projects.

Prerequisites / notice
Introductory GIS course

Literature

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract
Advanced course in geoinformation technologies: conceptual and logical modelling of networks, 3D- and 4D-data and spatial processes in GIS; raster data structures and operations; mobile GIS; Internet and GIS; interoperability and data transfer; legal and technical foundations of spatial data infrastructures (SDI)

Objective
Students will be able to carry out the following phases of a GIS project: data modelling, mobile data acquisition and analysis, Web publication of data and integration of interoperable geospatial web services into a Spatial Data Infrastructure (SDI).

Students will deepen their knowledge of conceptual and logical modeling by means of the particular requirements of networks as well as 3D- and 4D-data.

Literature

Spatial Development and Infrastructure Systems Master - Key for Type

| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |
| W | Eligible for credits | Dr | Suitable for doctorate |

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS

Special students and auditors need special permission from the lecturers.
Computational Science and Engineering Bachelor

First Year Compulsory Courses

First Year Examination Block 1

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-0151-00L</td>
<td>Linear Algebra</td>
<td>O</td>
<td>5</td>
<td>3V+2U</td>
<td>V. C. Gradinaru</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Contents: Linear systems - the Gaussian algorithm, matrices - LU decomposition, determinants, vector spaces, least squares - QR decomposition, linear maps, eigenvalue problem, normal forms - singular value decomposition; numerical aspects; introduction to MATLAB.</td>
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<td></td>
<td>Objective</td>
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<td></td>
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<td>Einführung in die Lineare Algebra für Ingenieure unter Berücksichtigung numerischer Aspekte</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>eigenes Aufschrift und K. Nipp / D. Stoffer, Lineare Algebra, vdf Hochschulverlag, 5. Auflage 2002</td>
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<td>Taught competencies</td>
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<td>Domain A - Subject-specific Competencies: Concepts and Theories assessed</td>
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<td>Domain C - Social Competencies: Communication not assessed</td>
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<td>Domain D - Personal Competencies: Critical Thinking assessed</td>
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<tr>
<td>252-0025-01L</td>
<td>Discrete Mathematics</td>
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<td>7</td>
<td>4V+2U</td>
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<td>Content: Mathematical reasoning and proofs, abstraction. Sets, relations (e.g., equivalence and order relations), functions, (un-)countability, number theory, algebra (groups, rings, fields, polynomials, subalgebras, morphisms), logic (propositional and predicate logic, proof calculi),</td>
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<td></td>
<td>Objective</td>
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<td>The primary goals of this course are (1) to introduce the most important concepts of discrete mathematics, (2) to understand and appreciate the role of abstraction and mathematical proofs, and (3) to discuss a number of applications, e.g., in cryptography, coding theory, and algorithm theory.</td>
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<tr>
<td></td>
<td>Content</td>
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<td>See course description.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
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<td></td>
<td>English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.</td>
</tr>
<tr>
<td>252-0856-00L</td>
<td>Computer Science</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>F. O. Friedrich Wicker, R. Sasse</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>The course covers the fundamental concepts of computer programming with a focus on systematic algorithmic problem solving. Taught language is C++. No programming experience is required.</td>
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<tr>
<td></td>
<td>Objective</td>
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<td>Primary educational objective is to learn programming with C++. After having successfully attended the course, students have a good command of the mechanisms to construct a program. They know the fundamental control and data structures and understand how an algorithmic problem is mapped to a computer program. They have an idea of what happens &quot;behind the scenes&quot; when a program is translated and executed. Secondary goals are an algorithmic computational thinking, understanding the possibilities and limits of programming and to impart the way of thinking like a computer scientist.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
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<td>The course covers fundamental data types, expressions and statements, (limits of) computer arithmetic, control statements, functions, arrays, structural types and pointers. The part on object orientation deals with classes, inheritance and polymorphism; simple dynamic data types are introduced as examples. In general, the concepts provided in the course are motivated and illustrated with algorithms and applications.</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>English lecture notes will be provided during the semester. The lecture notes and the lecture slides will be made available for download on the course web page. Exercises are solved and submitted online.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
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<td>See course description.</td>
</tr>
</tbody>
</table>

First Year Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-0231-10L</td>
<td>Analysis I</td>
<td>O</td>
<td>8</td>
<td>4V+3U</td>
<td>T. Rivière</td>
</tr>
<tr>
<td></td>
<td>Students in BSc EEIT may instead register for 401-1261-07L Analysis I: One Variable (for BSc Mathematics, BSc Physics and BSc Interdisciplinary Science (Phys Chem)) and take the performance assessment of the corresponding two-semester course. Students in BSc EEIT who wish to register for 401-1261-07L/401-1262-07L Analysis I: One Variable/Analysis II: Several Variables instead of 401-0231-10L/401-0232-10L Analysis I/Analysis 2 must get in touch with the Study Administration before the registration.</td>
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<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>Reelle und komplexe Zahlen, Grenzwerte, Folgen, Reihen, Potenzreihen, stetige Abbildungen, Differential- und Integralsymbolen, Grenzwerte, Variablen, Einführung in gewöhnliche Differentialgleichungen</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
<td>Einführung in die Grundlagen der Analysis</td>
</tr>
<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Christian Blatter: Ingenieur-Analyse (Kapitel 1-4)</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>Konrad Koenigsberger, Analysis I. Christian Blatter, Analysis I.</td>
</tr>
<tr>
<td>402-0043-00L</td>
<td>Physics I</td>
<td>O</td>
<td>4</td>
<td>3V+1U</td>
<td>J. Home</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
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<td></td>
<td>Introduction to the concepts and tools in physics with the help of demonstration experiments: mechanics of point-like and ridged bodies, periodic motion and mechanical waves.</td>
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<td></td>
<td>Objective</td>
<td></td>
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<td></td>
<td>The concepts and tools in physics, as well as the methods of an experimental science are taught. The student should learn to identify, communicate and solve physical problems in his/her own field of science.</td>
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<tr>
<td></td>
<td>Content</td>
<td></td>
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<td></td>
<td>Mechanics (motion, Newton's laws, work and energy, conservation of momentum, rotation, gravitation, fluids) Periodic Motion and Waves (periodic motion, mechanical waves, acoustics).</td>
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<tr>
<td></td>
<td>Lecture notes</td>
<td></td>
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<td></td>
<td>The lecture follows the book &quot;Physics&quot; by Paul A. Tipler.</td>
</tr>
<tr>
<td></td>
<td>Literature</td>
<td></td>
<td></td>
<td></td>
<td>Paul A. Tipler and Gene P. Mosca, Physics (for Scientists and Engineers), W. H. Freeman and Company</td>
</tr>
<tr>
<td>Number</td>
<td>Title</td>
<td>Type</td>
<td>ECTS</td>
<td>Hours</td>
<td>Lecturers</td>
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<tr>
<td>401-0353-00L</td>
<td>Analysis 3</td>
<td>O</td>
<td>4 credits</td>
<td>2V+2U</td>
<td>M. Iacobelli</td>
</tr>
<tr>
<td>Abstract</td>
<td>In this lecture we treat problems in applied analysis. The focus lies on the solution of quasilinear first order PDEs with the method of characteristics, and on the study of three fundamental types of partial differential equations of second order: the Laplace equation, the heat equation, and the wave equation.</td>
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<tr>
<td>Objective</td>
<td>The aim of this class is to provide students with a general overview of first and second order PDEs, and teach them how to solve some of these equations using characteristics and/or separation of variables.</td>
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<tr>
<td>Content</td>
<td>1.) General introduction to PDEs and their classification (linear, quasilinear, semilinear, nonlinear / elliptic, parabolic, hyperbolic)</td>
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<td>2.) Quasilinear first order PDEs</td>
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<tr>
<td></td>
<td>- Solution with the method of characteristics</td>
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<td>- Conservation laws</td>
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<td>3.) Hyperbolic PDEs</td>
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<td></td>
<td>- wave equation</td>
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<td>- d’Alembert formula in (1+1)-dimensions</td>
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<td>- method of separation of variables</td>
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<td>4.) Parabolic PDEs</td>
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<td></td>
<td>- heat equation</td>
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<td></td>
<td>- maximum principle</td>
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<td>- method of separation of variables</td>
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<td>5.) Elliptic PDEs</td>
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<tr>
<td></td>
<td>- Laplace equation</td>
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<td>- maximum principle</td>
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<td>- method of separation of variables</td>
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<td></td>
<td>- variational method</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Analysis I and II, Fourier series (Complex Analysis)</td>
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<tr>
<td>401-0647-00L</td>
<td>Introduction to Mathematical Optimization</td>
<td>O</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>D. Adjishvili</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to basic techniques and problems in mathematical optimization, and their applications to a variety of problems in engineering.</td>
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<tr>
<td>Objective</td>
<td>The goal of the course is to obtain a good understanding of some of the most fundamental mathematical optimization techniques used to solve linear programs and basic combinatorial optimization problems. The students will also practice applying the learned models to problems in engineering.</td>
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<tr>
<td>Content</td>
<td>Topics covered in this course include:</td>
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<td></td>
<td>- Linear programming (simplex method, duality theory, shadow prices, ...).</td>
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<td></td>
<td>- Basic combinatorial optimization problems (spanning trees, shortest paths, network flows, ...).</td>
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<td></td>
<td>- Modelling with mathematical optimization: applications of mathematical programming in engineering.</td>
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<tr>
<td>Literature</td>
<td>Information about relevant literature will be given in the lecture.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This course is meant for students who did not already attend the course &quot;Mathematical Optimization&quot;, which is a more advance lecture covering similar topics. Compared to &quot;Mathematical Optimization&quot;, this course has a stronger focus on modeling and applications.</td>
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<tr>
<td>401-2673-00L</td>
<td>Numerical Methods for CSE</td>
<td>O</td>
<td>9 credits</td>
<td>2V+2U+4P</td>
<td>R. Hiptmair</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods. The exercises involve actual implementation of numerical methods in C++.</td>
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<tr>
<td>Objective</td>
<td>* Knowledge of the fundamental algorithms in numerical mathematics</td>
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<td>* Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms</td>
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<td>* Ability to choose the appropriate numerical method for concrete problems</td>
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<td>* Ability to interpret numerical results</td>
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<td>* Ability to implement numerical algorithms efficiently</td>
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<tr>
<td>Content</td>
<td>* Computing with Matrices and Vectors</td>
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<td></td>
<td>* Direct Methods for linear systems of equations</td>
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<td></td>
<td>* Least Squares Techniques</td>
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<td></td>
<td>* Data Interpolation and Fitting</td>
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<td></td>
<td>* Iterative Methods for non-linear systems of equations</td>
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<tr>
<td></td>
<td>* Filtering Algorithms</td>
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<tr>
<td></td>
<td>* Approximation of Functions</td>
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<tr>
<td></td>
<td>* Numerical Quadrature</td>
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<tr>
<td>Lecture notes</td>
<td>Lecture materials (PDF documents and codes) will be made available to the participants through the course web page, whose address will be announced in the beginning of the course.</td>
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<tr>
<td></td>
<td>M. Hanke-Bourgeois &quot;Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens&quot;, BG Teubner, 2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>P. Deuflhard and A. Hohmann, &quot;Numerische Mathematik I&quot;, DeGruyter, 2002</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Knowledge of C++ is taken for granted.</td>
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</tbody>
</table>
### Block G2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>402-0811-00L</td>
<td>Programming Techniques for Scientific Simulations I</td>
<td>O</td>
<td>5</td>
<td>4G</td>
<td>R. Käppeli</td>
</tr>
<tr>
<td>Abstract</td>
<td>This lecture provides an overview of programming techniques for scientific simulations. The focus is on basic and advanced C++ programming techniques and scientific software libraries. Based on an overview over the hardware components of PCs and supercomputers, optimization methods for simulation codes are explained.</td>
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<tr>
<td>Objective</td>
<td>The goal of the course is that students learn basic and advanced programming techniques and scientific software libraries as used and applied for scientific simulations.</td>
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</tr>
<tr>
<td>252-0061-00L</td>
<td>Systems Programming and Computer Architecture</td>
<td>O</td>
<td>7</td>
<td>4V+2U</td>
<td>T. Roscoe, A. Klimovic</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to systems programming. C and assembly language, floating point arithmetic, basic translation of C into assembler, compiler optimizations, manual optimizations. How hardware features like superscalar architecture, exceptions and interrupts, caches, virtual memory, multicore processors, devices, and memory systems function and affect correctness, performance, and optimization.</td>
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<tr>
<td>Objective</td>
<td>The course objectives are for students to:</td>
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<tr>
<td></td>
<td>1. Develop a deep understanding of, and intuition about, the execution of all the layers (compiler, runtime, OS, etc.) between programs in high-level languages and the underlying hardware: the impact of compiler decisions, the role of the operating system, the effects of hardware on code performance and scalability, etc.</td>
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<td>2. Be able to write correct, efficient programs on modern hardware, not only in C but high-level languages as well.</td>
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<td>3. Understand Systems Programming as a complement to other disciplines within Computer Science and other forms of software development.</td>
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<tr>
<td>Content</td>
<td>This course does not cover how to design or build a processor or computer.</td>
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</tbody>
</table>
| Lecture notes| - C programming  
- Integers  
- Pointers and dynamic memory allocation  
- Basic computer architecture  
- Compiling C control flow and data structures  
- Code vulnerabilities  
- Implementing memory allocation  
- Linking  
- Floating point  
- Optimizing compilers  
- Architecture and optimization  
- Caches  
- Exceptions  
- Virtual memory  
- Multicore  
- Devices |
| Literature   | The course is based in part on "Computer Systems: A Programmer's Perspective" (3rd Edition) by R. Bryant and D. O'Hallaron, with additional material. |
| Prerequisites / notice | 252-0029-00L Parallel Programming  
252-0028-00L Design of Digital Circuits |

### Block G3

All course units within Block G3 are offered in the spring semester.

### Block G4

All course units within Block G4 are offered in the spring semester.
Module A

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>

Abstract
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

Objective
With manufacturing processes reaching its limits in terms of transistor density on today's computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the "think parallel" mind-set of developers is still lagging behind.

Content
1. Hardware and Architecture: Moore's Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn's taxonomy, Vector instructions (for Intel x86)
2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)
3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models
4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl's Law, Strong and weak scaling analysis
5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

Prerequisites / notice
A basic understanding of computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

Module B

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-2800-00L</td>
<td>Design of Parallel and High-Performance Computing</td>
<td>W</td>
<td>9</td>
<td>3V+2U+3A</td>
<td>T. Hoefler, M. Püschel</td>
</tr>
</tbody>
</table>

Abstract
Advanced topics in parallel and high-performance computing.

Objective
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites / notice
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

Core Courses from Group II
No offering in the Autumn Semester.

Fields of Specialization

Astrophysics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-7851-00L</td>
<td>Theoretical Astrophysics (University of Zurich)</td>
<td>W</td>
<td>10</td>
<td>4V+2U</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

Abstract
This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

Content
This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.
Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between:

Course Materials:
1. The Physics of Astrophysics, Volume 1: Radiation by Frank H. Shu
2. The Physics of Astrophysics, Volume 2: Gas Dynamics by Frank H. Shu
3. Foundations of radiation hydrodynamics, Dimitri Mihalas and Barbara Weibel-Mihalas
4. Radiative Processes in Astrophysics, George B. Rybicki and Alan P. Lightman
5. Galactic Dynamics, James Binney and Scott Tremaine

Prerequisites / notice
This is a full black board ad chalk experience for students with a strong background in mathematics and physics.

Prerequisites:
Introduction to Astrophysics
Mathematical Methods for the Physicist
Quantum Mechanics
(All preferred but not obligatory)

Prior Knowledge:
Mechanics
Quantum Mechanics and atomic physics
Thermodynamics
Fluid Dynamics
Electrodynamics

401-7855-00L Computational Astrophysics (University of Zurich) W 6 credits 2V L. M. Mayer

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: AST245

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadline.s.html

Objective
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes

Content
1. Integration of ODE, Hamiltonians and Symplectic integration techniques, time adaptivity, time reversibility
2. Large-N gravity calculation, collisionless N-body systems and their simulation
3. Fast Fourier Transform and spectral methods in general
4. Eulerian Hydrodynamics: Upwinding, Riemann solvers, Limiters
5. Lagrangian Hydrodynamics: The SPH method
6. Resolution and instabilities in Hydrodynamics
7. Initial Conditions: Cosmological Simulations and Astrophysical Disks
8. Physical Approximations and Methods for Radiative Transfer in Astrophysics

Literature
Galactic Dynamics (Binney & Tremaine, Princeton University Press),
Computer Simulation using Particles (Hockney & Eastwood CRC press),
Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh)

Prerequisites / notice
Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial

Physics of the Atmosphere

Number Title Type ECTS Hours Lecturers
701-0023-00L Atmosphere W 3 credits 2V E. Fischer, T. Peter

Abstract
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiative, condensation, clouds, oxidation capacity and ozone layer.

Objective
Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

Content
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Lecture notes
Written information will be supplied.

Literature

Chemistry

Number Title Type ECTS Hours Lecturers
529-0004-01L Classical Simulation of (Bio)Molecular Systems W 6 credits 4G P. H. Hünenberger, J. Dolenc, S. Riniker

Abstract
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Objective
Introduction to classical (atomistic) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

Content
Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

Lecture notes
The powerpoint slides of the lectures will be made available weekly on the website in pdf format (on the day preceding each lecture).

Literature
See: www.csms.ethz.ch/education/CSBMS

Prerequisites / notice
Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

Fluid Dynamics
### Systems and Control

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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2+2</td>
<td>F. Dörfler</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<td>Objective</td>
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<td>Content</td>
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<td></td>
<td>Literature</td>
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<td></td>
<td>Prerequisites / notice</td>
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<td>Signals and Systems Theory II.</td>
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<td></td>
<td>MATLAB is used for system analysis and simulation.</td>
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### Robotics

Only one of the two course units
227-0045-00L Image Analysis and Computer Vision may be recognised for credits. More precisely, it is also not allowed to have recognised one course unit for the Bachelor's and the other course unit for the Master's degree.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3+2</td>
<td>J. M. Buhmann, C. Cotini Jimenez</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.</td>
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</tbody>
</table>
Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments. Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-3210-00L  Deep Learning  W  8 credits  3V+2U+2A  F. Perez Cruz, A. Lucchi

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
The course requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

Advanced Machine Learning
https://ml2.inf.ethz.ch/courses/aml/

Computational Intelligence Lab
http://da.inf.ethz.ch/teaching/2019/CIL/

Introduction to Machine Learning
https://ias.inf.ethz.ch/teaching/introml-S19

Statistical Learning Theory
http://m2.inf.ethz.ch/courses/slt/

Computational Statistics
https://stat.ethz.ch/lectures/ss19/comp-stats.php

Probabilistic Artificial Intelligence
https://las.inf.ethz.ch/teaching/pai-f18

263-5210-00L  Probabilistic Artificial Intelligence  W  8 credits  3V+2U+2A  A. Krause

Abstract
This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.
Introduction to Dynamic Programming and Optimal Control.

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those problems.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

---

Image Analysis and Computer Vision

The aim of this course is to provide students with a good understanding of computer vision and image analysis techniques. The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Objective

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those problems.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Content

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

Prerequisites / notice

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

---

Dynamic Programming and Optimal Control

Introduction to Dynamic Programming and Optimal Control.

Objective

Covers the fundamental concepts of Dynamic Programming & Optimal Control. The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Content

Robot dynamics. We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

Objective

The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

Content

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

Prerequisites / notice

The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

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Physics

Number  Title                              Type  ECTS  Hours  Lecturers
402-0809-00L Introduction to Computational Physics  W  8 credits  2+2U  A. Adelmann

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Objective

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, classical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem.

---
Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

Lecture notes and slides are available online and will be distributed if desired.

Literature recommendations and references are included in the lecture notes.

Lecture and exercise lessons in English, exams in German or in English

#### Computational Finance

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>401-3913-01L</td>
<td>Mathematical Foundations for Finance</td>
<td>W</td>
<td>4</td>
<td>3V+2U</td>
<td>B. Acciaio</td>
</tr>
<tr>
<td>Abstract</td>
<td>First introduction to main modelling ideas and mathematical tools from mathematical finance</td>
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<tr>
<td>Objective</td>
<td>This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.</td>
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<td>Content</td>
<td>Topics to be covered include</td>
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<td>- financial market models in finite discrete time</td>
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<td>- absence of arbitrage and martingale measures</td>
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<td>- valuation and hedging in complete markets</td>
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<td>- basics about Brownian motion</td>
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<td></td>
<td>- stochastic integration</td>
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<tr>
<td></td>
<td>- stochastic calculus; Itô's formula, Girsanov transformation, Itô's representation theorem</td>
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<td></td>
<td>- Black-Scholes formula</td>
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<tr>
<td>Literature</td>
<td>Lecture notes will be sold at the beginning of the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Results and facts from probability theory as in the book &quot;Probability Essentials&quot; by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course &quot;Wahrscheinlichkeitslehre&quot;.) For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.</td>
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<th>Number</th>
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<tbody>
<tr>
<td>401-4657-00L</td>
<td>Numerical Analysis of Stochastic Ordinary Differential Equations</td>
<td>W</td>
<td>6</td>
<td>3V+1U</td>
<td>A. Stein</td>
</tr>
<tr>
<td>Abstract</td>
<td>Course on numerical approximations of stochastic ordinary differential equations driven by Wiener processes. These equations have several applications, for example in financial option valuation. This course also contains an introduction to random number generation and Monte Carlo methods for random variables.</td>
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<tr>
<td>Objective</td>
<td>The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this course the teacher deems a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.</td>
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<tr>
<td>Content</td>
<td>Generation of random numbers</td>
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<td>Monte Carlo methods for the numerical integration of random variables</td>
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<td></td>
<td>Stochastic processes and Brownian motion</td>
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<td></td>
<td>Stochastic ordinary differential equations (SODEs)</td>
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<tr>
<td></td>
<td>Numerical approximations of SODEs</td>
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<tr>
<td></td>
<td>Applications to computational finance: Option valuation</td>
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<tr>
<td>Literature</td>
<td>There will be English, typed lecture notes for registered participants in the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Mandatory: Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.</td>
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<td>a) mandatory courses: Elementary Probability, Probability Theory I.</td>
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<td>b) recommended courses: Stochastic Processes.</td>
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</table>

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

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<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>J. Smajic</td>
</tr>
<tr>
<td>Abstract</td>
<td>This module consists of (a) an introduction to fundamental equations of electromagnetics, mechanics and heat transfer, (b) a detailed overview of numerical methods for field simulations, and (c) practical examples solved in form of small projects.</td>
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</table>

Objective

Basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main concepts of numerical methods for physical modelling and simulation. Ability (a) to develop own field simulation programs, (b) to select an appropriate field solver for a given problem, (c) to perform field simulations, (d) to evaluate the obtained results, and (e) to interactively improve the models until sufficiently accurate results are obtained.

Content

The module begins with an introduction to the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. After the introduction follows a detailed overview of the available numerical methods for solving electromagnetical, thermal and mechanical boundary value problems. This part of the course contains a general introduction into numerical methods, differential and integral forms, linear equation systems, Finite Difference Method (FDM), Boundary Element Method (BEM), Method of Moments (MoM), Multiple Multipole Program (MMP) and Finite Element Method (FEM). The theoretical part of the course finishes with a presentation of multiphysics simulations through several practical examples of HF-engineering such as coupled electromagnetic-mechanical and electromagnetic-thermal analysis of MEMS.

In the second part of the course the students will work in small groups on practical simulation problems. For solving practical problems the students can develop and use own simulation programs or chose an appropriate commercial field solver for their specific problem. This practical simulation work of the students is supervised by the lecturers.

Geophysics

Recommended combinations:

- Subject 1 + Subject 2
- Subject 1 + Subject 3
- Subject 2 + Subject 3
- Subject 3 + Subject 4
- Subject 5 + Subject 6 + Subject 8
- Subject 4 + Subject 5
- Subject 7 + Subject 8

Geophysics: Subject 1

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<tr>
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<th>ECTS</th>
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<tbody>
<tr>
<td>651-4007-00L</td>
<td>Continuum Mechanics</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Gerya</td>
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</tbody>
</table>

Abstract

In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

Objective

The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth's mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.

Content

A provisional week-by-week schedule (subject to change) is as follows:

Weeks 1, 2: The continuity equation
Exercises: Computing the divergence of velocity field.

Weeks 3, 4: Density and gravity
Exercises: Computing density, thermal expansion and compressibility from an equation of state. Derivation of gravitational acceleration and its divergence from gravitational potential.

Weeks 5, 6: Stress and strain

Weeks 7, 8: The momentum equation
- Deriving momentum equation. Computing velocity for magma flow in a channel.

Week 9: Viscous rheology of rocks
Theory: Solid-state creep of minerals and rocks as themajor mechanism of deformation of the Earths interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws.
Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

Weeks 10, 11: The heat conservation equation

Week 12, 13: Elasticity and plasticity


Lecture notes

GRADING will be based on homeworks (1/3) and oral exam (2/3).

Script and Exam questions are available by request tgerya@ethz.ch

Literature

### Computational Geophysics: Subject 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>651-4241-00L</td>
<td>Numerical Modelling I and II: Theory and Applications</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>T. Gerya</td>
</tr>
</tbody>
</table>

**Abstract**

In this 13-week sequence, students learn how to write programs from scratch to solve partial differential equations that are useful for Earth science applications. Programming will be done in MATLAB and will use the finite-difference method and marker-in-cell technique. The course will emphasise a hands-on learning approach rather than extensive theory.

**Objective**

The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.

**Content**

A provisional week-by-week schedule (subject to change) is as follows:

- **Week 1**: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.
- **Week 2**: Direct and iterative methods for obtaining numerical solutions. Solving of 2D Poisson equation with direct method. Solving of 2D Poisson equation with Gauss-Seidel and Jacobi iterative methods.
- **Week 3**: Solving momentum and continuity equations in case of constant viscosity with stream function/vorticity formulation.
- **Weeks 4**: Staggered grid for formulating momentum and continuity equations. Indexing of unknowns. Solving momentum and continuity equations in case of constant viscosity using pressure-velocity formulation with staggered grid.
- **Weeks 5**: Conservative finite differences for the momentum equation. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.
- **Week 6**: Advection in 1-D. Eulerian methods. Marker-in-cell method. Comparison of different advection methods and their accuracy.
- **Week 7**: Advection in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.
- **Week 9**: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.
- **Week 10**: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.
- **Week 11**: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.
- **Week 12**: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.
- **Week 13**: Subgrid diffusion of temperature and its implementation. Implementation of temperature-, pressure- and strain rate-dependent viscosity, temperature- and pressure-dependent density and temperature-dependent thermal conductivity to the thermomechanical code. Final project description for slab breakoff modeling.

**Literature**


### Computational Geophysics: Subject 3

*Offered in the spring semester*

### Computational Geophysics: Subject 4

*Offered in the spring semester*

### Computational Geophysics: Subject 5

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4014-00L</td>
<td>Seismic Waves II</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>T. Diehl, F. Lanza, A. Obermann</td>
</tr>
</tbody>
</table>

**Abstract**

This course provides an overview on the most widely used seismological methods to image the Earth’s interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

**Objective**

Understand the strengths and weaknesses of various active and passive tomographic methods to image the structure of the Earth.

## Geophysics: Subject 6

Offered in the spring semester

## Geophysics: Subject 7

Offered in the spring semester

## Geophysics: Subject 8

### Numerical Modelling in Fortran

#### 651-4273-00L

**Title:** Numerical Modelling in Fortran  
**Type:** W  
**ECTS:** 3 credits  
**Hours:** 2V  
**Lecturers:** P. Tackley

**Abstract:** This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

**Objective:** Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

**Lecture notes:** See [http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html](http://jupiter.ethz.ch/~pjt/FORTRAN/FortranClass.html)

**Taught competencies:**
- Domain A - Subject-specific Competencies: Techniques and Technologies - assessed
- Domain B - Method-specific Competencies: Media and Digital Technologies - assessed
- Problem-solving - assessed

### Computational Systems Biology

#### 636-0007-00L

**Title:** Computational Systems Biology  
**Type:** W  
**ECTS:** 6 credits  
**Hours:** 3V+2U  
**Lecturers:** J. Stelling

**Abstract:** Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

**Objective:** The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

**Content:** Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

**Lecture notes:** [http://www.csb.ethz.ch/education/lectures.html](http://www.csb.ethz.ch/education/lectures.html)

**Literature:**

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### Spatio-Temporal Modelling in Biology

#### 636-0706-00L

**Title:** Spatio-Temporal Modelling in Biology  
**Type:** W  
**ECTS:** 4 credits  
**Hours:** 3G  
**Lecturers:** D. Iber

**Abstract:** This course focuses on modeling spatio-temporal problems in biology, in particular on the cell and tissue level. The main focus is on mechanisms and concepts, but mathematical and numerical techniques are introduced as required. Biological examples discussed in the course provide an introduction to key concepts in developmental biology.

**Objective:** Students will learn state-of-the-art approaches to modeling spatial effects in dynamical biological systems. The course provides an introduction to dynamical system, and covers the mathematical analysis of pattern formation in growing, developing systems, as well as the description of mechanical effects at the cell and tissue level. The course also provides an introduction to image-based modelling, i.e. the use of microscopy data for model development and testing. The course covers classic as well as current approaches and exposes students to open problems in the field. In this way, the course seeks to prepare students to conduct research in the field. The course prepares students for research in developmental biology, as well as for applications in tissue engineering, and for biomedical research.

**Content:**
- 1. Introduction to Modelling in Biology  
- 2. Morphogen Gradients  
- 3. Dynamical Systems  
- 4. Cell-cell Signalling (Dr Boaretto)  
- 5. Travelling Waves  
- 6. Turing Patterns  
- 7. Chemotaxis  
- 8. Mathematical Description of Growing Biological Systems  
- 9. Image-Based Modelling  
- 10. Tissue Mechanics  
- 11. Cell-based Tissue Simulation Frameworks  
- 12. Plant Development (Dr Dumont)  
- 13. Growth Control  
- 14. Summary

**Lecture notes:** All lecture material will be made available online [https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html](https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html)
Introduction to Virtual Reality; basics of augmented reality; interaction with digital data, tangible user interfaces (TUI); basics of
Visualization, Simulation and Interaction - Virtual Reality
The course provides an introduction into stochastic methods that are applicable for example for the description and modeling of turbulent
and subsurface flows. Moreover, mathematical techniques are presented that are used to quantify uncertainty in various engineering
applications.

Domain B - Method-specific Competencies

Domain D - Personal Competencies

Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

151-0317-00L Visualization, Simulation and Interaction - Virtual Reality II

W 4 credits 3G A. Kunz

Abstract
This lecture provides deeper knowledge on the possible applications of virtual reality, its basic technology, and future research fields. The
goal is to provide a strong knowledge on Virtual Reality for a possible future use in business processes.

Objective
Virtual Reality can not only be used for the visualization of 3D objects, but also offers a wide application field for small and medium
erprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data,
enterprises (SME). This could be for instance an enabling technology for net-based collaboration, the transmission of images and other data,
to discover the enancements and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to
discovering solutions.

Content
This course considers the structure and function of biological neural networks at different levels. The function of neural networks lies fundamentally in their wiring and in the electro-chemical properties of nerve cell membranes. Thus, the biological structure of the nerve cell needs to be understood if biologically-realistic models are to be constructed. These simpler models are used to estimate the electrical
current flow through dendritic cables and explore how a more complex geometry of neurons influences this current flow. The active
properties of nerves are studied to understand both sensory transduction and the generation and transmission of nerve impulses along
axons. The concept of local neuronal circuits arises in the context of the rules governing the formation of nerve connections and
topographic projections within the nervous system. Communication between neurons in the network can be thought of as information flow
across synapses, which can be modified by experience. We need an understanding of the action of inhibitory and excitatory
neurotransmitters and neuromodulators, so that the dynamics and logic of synapses can be interpreted. Finally, the neural architectures of
teedforward and recurrent networks will be discussed in the context of co-ordination, control, and integration of sensory and motor
information in neural networks.

In the 'electives' subcategory, at least two course units must be successfully completed.

Number Title Type ECTS Hours Lecturers
151-0709-00L Stochastic Methods for Engineers and Natural Scientists W 4 credits 4G D. W. Meyer-Massetti

Abstract
The course provides an introduction into stochastic methods that are applicable for example for the description and modeling of turbulent

Objective
By the end of the course you should be able to mathematically describe random quantities and their effect on physical systems. Moreover,
you should be able to develop basic stochastic models of such systems.

Content
- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation

Lecture notes
Detailed lecture notes will be provided.

Literature
Some textbooks related to the material covered in the course:

Taught competencies

domain A - Subject-specific Competencies

Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies

Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Domain C - Content-specific Competencies

Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-direction and Self-management assessed

Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, contact conditions and instability of structures. The principles of the nonlinear Finite-Element-Method (FEM) will be introduced for treating such problems. The finite element program ABAQUS is introduced to investigate real engineering problems.

The goal of the lecture is to provide the students with the fundamentals of the non linear Finite Element Method (FEM). The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the nonlinear Finite-Element-Methods are simulations of:

- Crash
- Collapse of structures
- Material behavior (metals and rubber)
- General forming processes

Special attention will be paid to the modeling of the nonlinear material behavior, thermo-mechanical processes and processes with large plastic deformations. The ability to independently create a virtual model which describes the complex non linear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems.

The course provides an introduction to non-linear finite element analysis. The treated sources of non-linearity are related to material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).

Content
- Introduction into FEM
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Element formulations
- Implicit and explicit FEM methods
- FEM formulations of coupled thermo-mechanical problems
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems

Lecture notes
Lecture slides
Lecture notes will be provided. However, students are encouraged to take their own notes.

Prerequisites
Mechanics 1, 2, Dynamics, Continuum Mechanics I and Introduction to FEA. Ideally also Continuum Mechanics II.

- Critical Thinking
- Cooperation and Teamwork
- Media and Digital Technologies
- Specifying Competencies
- Domain A - Subject-specific Competencies
- Concepts and Theories
- Domain B - Method-specific Competencies
- Analytical Competencies
- Domain C - Social Competencies
- Communication
- Domain D - Personal Competencies
- Creative Thinking
- assessed

4 credits
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

Content
- We will cover all aspects of high-performance computing ranging from architecture through programming to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

Prerequisites
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallelere Programmierung (parallel programing)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

4G
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages, Specification Models, Stochastic Discrete Event Systems, Worst-Case Event Systems, Verification, Network Calculus.
Objectives
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans. The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g., hitting a keyboard key, sending a message), some not (e.g., spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content
1. Introduction
2. Automata and Languages
3. Smarter Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes
Available

Literature
[bertsekas] Data Networks
Dimitri Bertsekas, Robert Gallager

[boudec] Network Calculus
J.-Y. Le Boudec, P. Thiran
Springer, 2001

[cassandras] Introduction to Discrete Event Systems
Christos Cassandras, Stéphane Lafortune

[fiat] Online Algorithms: The State of the Art
A. Fiat and G. Woeginger
D. Hochbaum

[schickinger] Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)
T. Schickinger, A. Steger
Springer, Berlin, 2001

[sipser] Introduction to the Theory of Computation
Michael Sipser

227-0116-00L

VLSI 1: HDL based design for FPGAs
6 credits
SG
F. K. Gürkaynak, L. Benini

Abstract
This first course in a series that extends over three consecutive terms is concerned with tailoring algorithms and with devising high performance hardware architectures for their implementation as ASIC or with FPGAs. The focus is on front end design using HDLs and automatic synthesis for producing industrial-quality circuits.

Objective
Understand Very-Large-Scale Integrated Circuits (VLSI chips), Application-Specific Integrated Circuits (ASIC), and Field-Programmable Gate-Arrays (FPGA). Know their organization and be able to identify suitable application areas. Become fluent in front-end design from architectural conception to gate-level netlists. How to model digital circuits with SystemVerilog. How to ensure they behave as expected with the aid of simulation, testbenches, and assertions. How to take advantage of automatic synthesis tools to produce industrial-quality VLSI and FPGA circuits. Gain practical experience with the hardware description language SystemVerilog and with industrial Electronic Design Automation (EDA) tools.

Content
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Literature
This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equipartition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

### Objective
- The fundamentals of Information Theory including Shannon's source coding and channel coding theorems
- The entropy rate of a source, Typical sequences, the asymptotic equipartition property, the source coding theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

### Literature
- A. Lapidoth, Introduction to Coding Theory
- T.M. Cover and J. Thomas, Elements of Information Theory (second edition)
At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and

**Objective**
The course is an introduction to some basic topics in signal processing and machine learning.

**Content**

**Lecture notes**
Lecture notes.

**Prerequisites / notice**
- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

**227-0971-00L Computational Psychiatry**

**Abstract**
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Objective**
This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

**Content**
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples. Furthermore, practical exercises provide in-depth exposure to different software packages. Please see http://www.translationalneuromodeling.org/cpcourse/ for details.

**Literature**

**252-0417-00L Randomized Algorithms and Probabilistic Methods**

**Abstract**
Las Vegas & Monte Carlo algorithms; inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, 3SAT, card shuffling, random walks

**Objective**
After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.

**Content**
Randomized Algorithms are algorithms that "flip coins" to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.

**Lecture notes**
Yes.

**Literature**

**252-0206-00L Visual Computing**

**Abstract**
This course acquaints students with core knowledge in computer graphics, image processing, multimedia and computer vision. Topics include: Graphics pipeline, perception and camera models, modeling, shading, global illumination, texturing, sampling, filtering, image representations, image and video compression, edge detection and optical flow.

**Objective**
This course provides an in-depth introduction to the core concepts of computer graphics, image processing, multimedia and computer vision. The course forms a basis for the specialization track Visual Computing of the CS master program at ETH.

**Content**
Course topics will include: Graphics pipeline, perception and color models, camera models, transformations and projection, projections, lighting, shading, global illumination, texturing, sampling theorem, Fourier transforms, image representations, convolution, linear filtering, diffusion, nonlinear filtering, edge detection, optical flow, image and video compression.

In theoretical and practical homework assignments students will learn to apply and implement the presented concepts and algorithms.

**Lecture notes**
A scriptum will be handed out for a part of the course. Copies of the slides will be available for download. We will also provide a detailed list of references and textbooks.

**Literature**

**252-0543-01L Computer Graphics**

**Abstract**
This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.

**Objective**
At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students’ curiosity to explore the field of computer graphics in subsequent courses or on their own.

**Content**
This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.

**Lecture notes**
No.

**Literature**
Books:
- High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting
- Multiple view geometry in computer vision
- Physically Based Rendering: From Theory to Implementation

Prerequisites / notice
Fundamentals of calculus and linear algebra, basic concepts of algorithms and data structures, programming skills in C++. Visual Computing course recommended.

252-0546-00L  Physically-Based Simulation in Computer Graphics  W  5 credits  2V+1U+1A  V. da Costa de Azevedo, B. Solenthaler, B. Thomaszewski

Abstract
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Objective
This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.

Content
The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.

Prerequisites / notice
Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++. Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.

252-0834-00L  Information Systems for Engineers  W  4 credits  2V+1U  G. Fourny

Abstract
This course provides the basics of relational databases from the perspective of the user.

We will discover why tables are so incredibly powerful to express relations, learn the SQL query language, and how to make the most of it. The course also covers support for data cubes (analytics).

Objective
This lesson is complementary with Big Data for Engineers as they cover different time periods of database history and practices -- you can take them in any order, even though it might be more enjoyable to take this lecture first.

After visiting this course, you will be capable to:
1. Explain, in the big picture, how a relational database works and what it can do in your own words.
2. Explain the relational data model (tables, rows, attributes, primary keys, foreign keys), formally and informally, including the relational algebra operators (select, project, rename, all kinds of joins, division, cartesian product, union, intersection, etc).
3. Perform non-trivial reading SQL queries on existing relational databases, as well as insert new data, update and delete existing data.
4. Design new schemas to store data in accordance to the real world's constraints, such as relationship cardinality.
5. Explain what bad design is and why it matters.
6. Adapt and improve an existing schema to make it more robust against anomalies, thanks to a very good theoretical knowledge of what is called "normal forms".
7. Understand how indices work (hash indices, B-trees), how they are implemented, and how to use them to make queries faster.
8. Access an existing relational database from a host language such as Java, using bridges such as JDBC.
9. Explain what data independence is all about and didn't age a bit since the 1970s.
10. Explain, in the big picture, how a relational database is physically implemented.
11. Know and deal with the natural syntax for relational data, CSV.
12. Explain the data cube model including slicing and dicing.
13. Store data cubes in a relational database.
14. Map cube queries to SQL.
15. Slice and dice cubes in a UI.

And of course, you will think that tables are the most wonderful object in the world.

Content
Using a relational database

1. Introduction
2. The relational model
3. Data definition with SQL
4. The relational algebra
5. Queries with SQL

Taking a relational database to the next level

6. Database design theory
7. Databases and host languages
8. Databases and host languages
9. Indices and optimization
10. Database architecture and storage

Analytics on top of a relational database

12. Data cubes

Outlook

13. Outlook
### 401-3627-00L High-Dimensional Statistics

**Abstract**  
"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

**Objective**  
Knowledge of methods and basic theory for high-dimensional statistical inference

**Content**  
- Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions;
- Non-convex loss functions and ℓ1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

**Literature**  

**Prerequisites / notice**  
Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Number of Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
</table>
| 401-3627-00L | 4 | - Lecture material (slides). 
- Book: "Database Systems: The Complete Book", H. Garcia-Molina, J.D. Ullman, J. Widom (It is not required to buy the book, as the library has it) 
For non-CS/DS students only, BSc and MSc 
Elementary knowledge of set theory and logic

### 401-4623-00L Time Series Analysis

**Abstract**  
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

**Objective**  
The goal of the course is to have a a good overview of the different types of time series and the approaches used in their statistical analysis.

**Content**  
This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.

The key topics which will be covered as:

- Stationarity 
- Autocorrelation 
- Trend estimation 
- Elimination of seasonality 
- Spectral analysis, spectral densities 
- Forecasting 
- ARMA, ARIMA, Introduction into GARCH models

**Literature**  
The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis

**Prerequisites / notice**  
Basic knowledge in probability and statistics

### 401-3901-00L Linear & Combinatorial Optimization

**Abstract**  
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

**Objective**  
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

**Content**  
Key topics include:
- Linear programming and polyhedra; 
- Flows and cuts; 
- Combinatorial optimization problems and polyhedral techniques; 
- Equivalence between optimization and separation.

**Literature**  

**Prerequisites / notice**  
Solid background in linear algebra.

**Taught competencies**

- **Domain A - Subject-specific Competencies**
  - Concepts and Theories: assessed
  - Techniques and Technologies: not assessed

- **Domain B - Method-specific Competencies**
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: not assessed
  - Problem-solving: assessed
  - Project Management: not assessed

- **Domain C - Social Competencies**
  - Communication: assessed
  - Cooperation and Teamwork: not assessed
  - Customer Orientation: not assessed
  - Leadership and Responsibility: not assessed
  - Self-presentation and Social Influence: not assessed
  - Sensitivity to Diversity: not assessed
  - Negotiation: not assessed

- **Domain D - Personal Competencies**
  - Adaptability and Flexibility: not assessed
  - Creative Thinking: assessed
  - Critical Thinking: not assessed
  - Integrity and Work Ethics: not assessed
  - Self-awareness and Self-reflection: not assessed
  - Self-direction and Self-management: not assessed
Neuromorphic Engineering I

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module IN404 at UZH. Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students/special-students-university-of-zurich.html

Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding of the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time simulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.: Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Particular: The course is highly recommended for those who intend to take the spring semester course 'Neuromorphic Engineering II', that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

Transport Phenomena I

Phenomenological approach to “Transport Phenomena” based on balance equations supplemented by thermodynamic considerations to formulate the undetermined fluxes in the local species mass, momentum, and energy balance equations; Solutions of a few selected problems relevant to materials science and engineering both analytical and using numerical methods.

Objective
The teaching goals of this course are on five different levels:
(1) Deep understanding of fundamentals: local balance equations, constitutive equations for fluxes, entropy balance, interfaces, idea of dimensionless numbers and scaling, ...
(2) Ability to use the fundamental concepts in applications
(3) Insight into the role of boundary conditions (mainly part 2)
(4) Knowledge of a number of applications
(5) Flavor of numerical techniques: finite elements and finite differences.

Content
Part 1 Approach to Transport Phenomena
Equilibrium Thermodynamics
Balance Equations
Forces and Fluxes
Applications
1. Measuring Transport Coefficients
2. Fluid mechanics
3. Combined heat and flow

Lecture notes

Literature

Prerequisites / notice
Complex numbers, Vector analysis (integrability; Gauss’ divergence theorem). Laplace and Fourier transforms. Ordinary differential equations (basic ideas). Linear algebra (matrices; functions of matrices; eigenvectors and eigenvalues; eigenfunctions). Probability theory (Gaussian distributions; Poisson distributions; averages; moments; variances; random variables). Numerical mathematics (integration). Equilibrium thermodynamics (Gibbs’ fundamental equation; thermodynamic potentials; Legendre transforms). Maxwell equations.

Programming and simulation techniques (Matlab, Monte Carlo simulations).

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
Problem-solving

Domain B - Method-specific Competencies
assessed
assessed
assessed

see also Fields of Specialization

Electives (CSE Master)

Additional Electives from the Fields of Specialization (CSE Master)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>651-4O53-05L</td>
<td>Boundary Layer Meteorology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>M. Rotach, P. Calanca</td>
</tr>
</tbody>
</table>
Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

### Objective

Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

### Content

- Introduction
- Turbulence
- Statistical treatment of turbulence, turbulent transport
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Spectral characteristics
- Concepts for non-ideal boundary layer conditions

### Lecture Notes

Available (i.e. in English)

### Literature


### Prerequisites / Notice

**Physics I, II, Environmental Fluid Dynamics**

**Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.**

**Understanding the dynamics of large-scale atmospheric flow**

**The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.**

**Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer. Examples are:**

* Operators derived from principles of relativistic quantum mechanics
* Relativistic effects + methods of relativistic quantum chemistry
* Open-shell molecules + spin-density functional theory
* New electron-correlation theories

**The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. Examples are the Born-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown that these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.**

**1) Introductory lecture: basics of quantum mechanics and quantum chemistry**
- 2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
- 3) Klein-Gordon and Dirac equation; the Dirac hydrogen atom
- 4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
- 5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
- 6) Relativistic effects in chemistry and the emergence of spin
- 7) Spin in density functional theory
- 8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group
- 9) Quantum chemistry without the Born-Oppenheimer approximation

**A set of detailed lecture notes will be provided, which will cover the whole course.**
The course provides an introduction to digital image analysis in modern flow diagnostics. Different techniques which are discussed include image velocimetry, laser induced fluorescence, liquid crystal thermography and interferometry. The physical foundations and measurement configurations are explained. Image analysis algorithms are presented in detail and programmed during the exercises.

Objective
- Introduction to modern imaging techniques and post processing algorithms with special emphasis on flow analysis and visualization.
- Understanding of hardware and software requirements and solutions.
- Development of basic programming skills for (generic) imaging applications.
- Frequently used image processing techniques (filtering, correlation processing, FFTs, color space transforms).
- Image Velocimetry (tracking, pattern matching, Doppler imaging).
- Surface pressure and temperature measurements (fluorescent paints, liquid crystal imaging, infrared thermography).
- Laser induced fluorescence.
- (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping.
- Wall shear and heat transfer measurements.
- Pattern recognition and feature extraction, proper orthogonal decomposition.
- Handouts will be made available.

Lecture notes
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Literature
2) F. Schwabl: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997 [english version available: F. Schwabl, Advanced Quantum Mechanics]
3) R. McWeeny: Methods of Molecular Quantum Mechanics, Academic Press, 1992

Note also the standard textbooks:
A) A. Szabo, N.S. Ostlund, Verlag, Dover Publications
B) I. N. Levine, Quantum Chemistry, Pearson

Prerequisites / notice
- Stronlgly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

151-0105-00L Quantitative Flow Visualization

Objective
- Fundamentals of optics, flow visualization and electronic image acquisition.
- Frequently used image processing techniques (filtering, correlation processing, FFTs, color space transforms).
- Image Velocimetry (tracking, pattern matching, Doppler imaging).
- Surface pressure and temperature measurements (fluorescent paints, liquid crystal imaging, infrared thermography).
- Laser induced fluorescence.
- (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping.
- Wall shear and heat transfer measurements.
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Lecture notes
- Handouts will be made available.

Literature
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Prerequisites / notice
- Stronlgly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

151-0109-00L Turbulent Flows

Abstract
- Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings. Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows

Lecture notes
- Computation and modelling of turbulent flows

Literature
- Computational fluid dynamics

151-0213-00L Fluid Dynamics with the Lattice Boltzmann Method

Abstract
- Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

Objective
- During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.
- Central element of the course is the compilation of a lattice Boltzmann code (using the framework specifically designed for this course).
- The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.
- Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

Lecture notes
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Literature
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Prerequisites / notice
- Stronlgly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

151-0105-00L Quantitative Flow Visualization

Objective
- Introduction to modern imaging techniques and post processing algorithms with special emphasis on flow analysis and visualization.
- Development of basic programming skills for (generic) imaging applications.
- Frequently used image processing techniques (filtering, correlation processing, FFTs, color space transforms).
- Image Velocimetry (tracking, pattern matching, Doppler imaging).
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- (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping.
- Wall shear and heat transfer measurements.
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Lecture notes
- Handouts will be made available.

Literature
- Pattern recognition and feature extraction, proper orthogonal decomposition.

Prerequisites / notice
- Stronlgly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

151-0109-00L Turbulent Flows

Abstract
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Lecture notes
- Computation and modelling of turbulent flows

Literature
- Computational fluid dynamics

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- The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.
- Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.
The course builds upon three parts:
I Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II Theoretical basis of statistical mechanics and kinetic equations.
III Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation; Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   Relativistic fluid dynamics; flows with phase transitions.

Lecture notes
Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice
The course addresses mainly graduate students (MSc/PhD) but BSc students can also attend.

252-0535-00L Advanced Machine Learning W 10 credits 3V+2U+4A J. M. Buhmann, C. Cotrini Jimenez
Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:
Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.
PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Abstract
The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Objective
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:
* stochastic models in molecular evolution
* phylogenetic & phylodynamic inference
* maximum likelihood and Bayesian statistics
Attendees will apply these concepts to a number of applications yielding biological insight into:
* epidemiology
* pathogen evolution
* macroevolution of species

Content
The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS.

Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylodynamics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny.
Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes
Lecture slides will be available on moodle.

Literature
The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:
* Yang, Z. 2006. Computational Molecular Evolution.
* Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.

Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course 'Introduction to Programming', which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.cbb.ethz.ch/news-events.html
For the Zurich-based students without R experience, we recommend the R course http://www.vvc.ethz.ch/Vorlesungsverzeichnis/lerneinheit.view?semkez=2018W&sansicht=KATALOGDATEN&lerneinheitId=123546&lang=de, or working through the script provided as part of this R course.

► Case Studies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>401-3667-71L</td>
<td>Case Studies Seminar (Autumn Semester 2021)</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>V. C. Gradinaru, R. Hiptmair, M. Reiher</td>
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</tbody>
</table>

Abstract
Invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list. Students have to register their presentations online on https://rw.ethz.ch/the-programme/case-studies.html by the first week of the teaching period.

Content
In the CSE Case Studies Seminar invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list (containing articles from, e.g., Nature, Science, Scientific American, etc.). If the underlying paper comprises more than 15 pages, two or three consecutive case studies presentations delivered by different students can be based on it. Consistency in layout, style, and contents of those presentations is expected.

Students have to register their presentations online on https://rw.ethz.ch/the-programme/case-studies.html by the first week of the teaching period.

Prerequisites / notice
The talks might be given via Zoom; talks in presence should be also streamed in Zoom.

75% attendance and a short presentation on a published paper out of a list or on some own project are mandatory.

Students have to register their presentations online until the second Wednesday of the semester on https://rw.ethz.ch/the-programme/case-studies.html

The student talks will be grouped by subject, so we'll decide the actual dates of the individual talks.

Students that realize that they will not fulfill this criteria have to contact the teaching staff or de-register before the end of semester from the Seminar if they want to avoid a "Fail" in their documents. Later de-registrations will not be considered.

Taught competencies

<table>
<thead>
<tr>
<th>Domain</th>
<th>Competencies</th>
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<tbody>
<tr>
<td>Domain A - Subject-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
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<td>Problem-solving</td>
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<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
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<td></td>
<td>Self-Direction and Self-management</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
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<td></td>
<td>Creative Thinking</td>
<td>not assessed</td>
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<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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</tbody>
</table>

Yang, Z. 2006. Computational Molecular Evolution.
* macroevolution of species
* pathogen evolution
* epidemiology

see Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended Science in Perspective (Type B) for D-MATH.

see Science in Perspective: Language Courses ETH/UZH

If you wish to have recognised 402-2000-00L Scientific Works in Physics instead of 401-2000-00L Scientific Works in Mathematics (as allowed for the CSE programme), take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having passed the performance assessment.

### Bachelor's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>401-2000-00L</td>
<td>Scientific Works in Mathematics</td>
<td>O</td>
<td>0 credits</td>
<td></td>
<td>M. Burger</td>
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<tr>
<td></td>
<td><strong>Target audience:</strong> Third year Bachelor students; Master students who cannot document to have received an adequate training in working scientifically.</td>
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<tr>
<td></td>
<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)</td>
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<td><strong>Objective</strong></td>
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<td>Learn the basic standards of scientific works in mathematics.</td>
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<td><strong>Content</strong></td>
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<td>- Types of mathematical works</td>
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<td>- Publication standards in pure and applied mathematics</td>
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<td>- Data handling</td>
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<td>- Ethical issues</td>
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<td>- Citation guidelines</td>
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<td><strong>Prerequisites / notice</strong></td>
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<tr>
<td>401-2000-01L</td>
<td>Lunch Sessions – Thesis Basics for Mathematics Students</td>
<td>Z</td>
<td>0 credits</td>
<td></td>
<td>Speakers</td>
</tr>
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<td></td>
<td><strong>Details and registration for the optional MathBib training course:</strong> <a href="https://www.math.ethz.ch/mathbib-schulungen">https://www.math.ethz.ch/mathbib-schulungen</a></td>
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<tr>
<td>402-2000-00L</td>
<td>Scientific Works in Physics</td>
<td>W</td>
<td>0 credits</td>
<td></td>
<td>C. Eichler</td>
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<td></td>
<td><strong>Target audience:</strong> Master students who cannot document to have received an adequate training in working scientifically.</td>
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<td><strong>Abstract</strong></td>
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<tr>
<td></td>
<td>Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.</td>
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<td></td>
<td>Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.</td>
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<tr>
<td>401-3990-18L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>14 credits</td>
<td>30D</td>
<td>Supervisors</td>
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<tr>
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<td><strong>Successful participation in the course unit 401-2000-00L Scientific Works in Mathematics or 402-2000-00L Scientific Works in Physics is required.</strong></td>
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<td><strong>For more information, see <a href="http://www.math.ethz.ch/intranet/students/study-administration/theses.html">www.math.ethz.ch/intranet/students/study-administration/theses.html</a></strong></td>
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<td></td>
<td><strong>Abstract</strong></td>
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<td></td>
<td>The BSc thesis concludes the curriculum. In their BSc thesis, students should demonstrate their ability to carry out independent, structured scientific work. The purpose of the BSc thesis is to deepen knowledge in a certain subject and to bring students into closer contact with applications in an existing computational group. The BSc thesis requires approximately 160 hours of work.</td>
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<td><strong>Objective</strong></td>
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<td>In their BSc thesis students should demonstrate their ability to carry out independent, structured scientific work. The purpose is to deepen knowledge in a certain subject and to enable students to collaborate in an existing scientific group to take a computational approach to problems encountered in applications.</td>
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<td><strong>Prerequisites / notice</strong></td>
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<td></td>
<td>The supervisor responsible for the Bachelor thesis defines the task and determines the start and the submission date. The Bachelor thesis concludes with a written report. The Bachelor thesis is graded.</td>
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### Bachelor Studies (Programme Regulations 2016)

#### Bachelor's Thesis (Programme Regulations 2016)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-3990-01L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>8 credits</td>
<td>11D</td>
<td>Supervisors</td>
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<tr>
<td></td>
<td><strong>Only for Computational Science and Engineering BSc, Programme Regulations 2016.</strong></td>
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</tbody>
</table>
### Scientific Works in Mathematics or 402-2000-00L

*Scientific Works in Physics is required.*

*For more information, see [www.math.ethz.ch/intranet/students/study-administration/theses.html](http://www.math.ethz.ch/intranet/students/study-administration/theses.html)*

<table>
<thead>
<tr>
<th>Abstract</th>
<th>The BSc thesis concludes the curriculum. In their BSc thesis, students should demonstrate their ability to carry out independent, structured scientific work. The purpose of the BSc thesis is to deepen knowledge in a certain subject and to bring students into closer contact with applications in an existing computational group. The BSc thesis requires approximately 160 hours of work.</th>
</tr>
</thead>
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<td>Objective</td>
<td>In their BSc thesis students should demonstrate their ability to carry out independent, structured scientific work. The purpose is to deepen knowledge in a certain subject and to enable students to collaborate in an existing scientific group to take a computational approach to problems encountered in applications.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The supervisor responsible for the Bachelor thesis defines the task and determines the start and the submission date. The Bachelor thesis concludes with a written report. The Bachelor thesis is graded.</td>
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</tbody>
</table>

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#### Computational Science and Engineering Bachelor - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>E-</th>
<th>Recommended, not eligible for credits</th>
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<tbody>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z</td>
<td>Courses outside the curriculum</td>
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<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr</td>
<td>Suitable for doctorate</td>
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#### Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
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<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
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<tr>
<td>K</td>
<td>colloquium</td>
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#### ECTS

*European Credit Transfer and Accumulation System*

- Special students and auditors need special permission from the lecturers.
Computational Science and Engineering Master

► Core Courses

In the ‘core courses’ subcategory, at least two course units must be successfully completed.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-4671-00L</td>
<td>Advanced Numerical Methods for CSE</td>
<td>W</td>
<td>9 credits</td>
<td>4V+2U+1P</td>
<td>S. Mishra</td>
</tr>
</tbody>
</table>

Abstract
This course will focus on teaching different advanced topics in numerical methods for science and engineering. The main aim would be to introduce novel algorithms and discuss their implementation.

Objective
-- Presentation of state of the art numerical methods in computational fluid dynamics.
-- Advanced implementation in C++
-- Introduction of the role of data in scientific computing, particularly in the context of uncertainty quantification (UQ).

Content
A selection of the following topics will be covered:

1. Advanced numerical methods in fluid dynamics:
   -- Finite volume schemes
   -- High-resolution schemes on both structured and unstructured grids

2. Uncertainty quantification in fluid dynamics
   -- Modeling of uncertainty in terms of random fields.
   -- Monte Carlo methods
   -- Multi-level Monte Carlo methods.
   -- Quasi-Monte Carlo methods.

Lecture notes
Lecture material will be created during the course and will be made available.

Prerequisites / notice
- Familiarity with basic numerical methods
- Knowledge of numerical methods for differential equations (as covered in the course “Numerical Methods for Partial Differential Equations”).

252-0535-00L Advanced Machine Learning               W    10 credits | 3V+2U+4A | J. M. Buhmann, C. Cotrini Jimenez

Abstract
Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective
Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

Content
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature

Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.
Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

► Fields of Specialization

► Astrophysics

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-7851-00L</td>
<td>Theoretical Astrophysics (University of Zurich)</td>
<td>W</td>
<td>10 credits</td>
<td>4V+2U</td>
<td>University lecturers</td>
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</tbody>
</table>

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.
UZH Module Code: ASTS12
Mind the enrolment deadlines at UZH: 
https://www.uzh.ch/cmsssl/en/studies/application/deadline s.html

Abstract
This course covers the foundations of astrophysical fluid dynamics, the Boltzmann equation, equilibrium systems and their stability, the structure of stars, astrophysical turbulence, accretion disks and their stability, the foundations of radiative transfer, collisionless systems, the structure and stability of dark matter halos and stellar galactic disks.

Content
This course covers the foundations of astrophysical fluid dynamics, the theory of collisions and the Boltzmann equation, the notion of equilibrium systems and their stability, the structure of stars, the theory of astrophysical turbulence, the theory of accretion disks and their stability, the foundations of astrophysical radiative transfer, the theory of collisionless system, the structure and stability of dark matter halos and stellar galactic disks.

Literature
Course Materials:
1- The Physics of Astrophysics, Volume 1: Radiation by Frank H. Shu
2- The Physics of Astrophysics, Volume 2: Gas Dynamics by Frank H. Shu
3- Foundations of radiation hydrodynamics, Dimitri Mihalas and Barbara Weibel-Mihalas
4- Radiative Processes in Astrophysics, George B. Rybicki and Alan P. Lightman
5- Galactic Dynamics, James Binney and Scott Tremaine

Prerequisites / notice
This is a full black board ad chalk experience for students with a strong background in mathematics and physics.

Objective
Acquire knowledge of main methodologies for computer-based models of astrophysical systems, the physical equations behind them, and train such knowledge with simple examples of computer programmes

Content
1. Integration of ODE, Hamiltonians and Sympletic integration techniques, time adaptivity, time reversibility
2. Large-N gravity calculation, collisionless N-body systems and their simulation
3. Fast Fourier Transform and spectral methods in general
4. Eulerian Hydrodynamics: Upwinding, Riemann solvers, Limiters
5. Lagrangian Hydrodynamics: The SPH method
6. Resolution and instabilities in Hydrodynamics
7. Initial Conditions: Cosmological Simulations and Astrophysical Disks
8. Physical Approximations and Methods for Radiative Transfer in Astrophysics

Literature
Galactic Dynamics (Binney & Tremaine, Princeton University Press),
Computer Simulation using Particles (Hockney & Eastwood CRC press),
Targeted journal reviews on computational methods for astrophysical fluids (SPH, AMR, moving mesh)

Prerequisites / notice
Some knowledge of UNIX, scripting languages (see www.physik.uzh.ch/lectures/informatik/python/ as an example), some prior experience programming, knowledge of C, C++ beneficial

Physics of the Atmosphere

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<th>Number</th>
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<tr>
<td>701-0023-00L</td>
<td>Atmosphere</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>E. Fischer, T. Peter</td>
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</tbody>
</table>

Abstract
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Objective
Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

Content
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Lecture notes
Written information will be supplied.

Literature

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>651-4053-05L</td>
<td>Boundary Layer Meteorology</td>
<td></td>
<td>4 credits</td>
<td>3G</td>
<td>M. Rotach, P. Calanca</td>
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</table>

Abstract
The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Objective
Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).
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<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>6</td>
<td>W</td>
<td>4G</td>
<td>P. H. Hünenberger, J. Dolenc, S. Riniker</td>
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</table>

### Objective
- The purpose of the seminar is to introduce students to the process of writing scientific proposals, including preparation of a master thesis proposal and evaluation of each other's work. An introduction to presentation skills is provided. The essential elements of a proposal, including the peer review process, are outlined and class exercises train participants in peer review skills, correction/feedback to the proposals of other participants, and introduction to peer review process.

### Content
- In this seminar, the process of writing a scientific proposal is introduced. The essential elements of a proposal, including the peer review process, are outlined and class exercises train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other's work. Furthermore, an introduction to presentation skills is provided.

### Prerequisites / notice
- In this seminar it is mandatory to write a proposal about an upcoming MSc thesis or semester project. If no such project is planned, this seminar cannot be taken. Please contact the lecturers (hanna.joos@env.ethz.ch) on time if you plan to take this seminar.

### Chemistry

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>529-0004-01L</td>
<td>Classical Simulation of (Bio)Molecular Systems</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>P. H. Hünenberger, J. Dolenc, S. Riniker</td>
</tr>
</tbody>
</table>

### Abstract
- Molecular models, classical force fields, configuration sampling, molecular dynamics simulation, boundary conditions, electrostatic interactions, analysis of trajectories, free-energy calculations, structure refinement, applications in chemistry and biology. Exercises: hands-on computer exercises for learning progressively how to perform an analyze classical simulations (using the package GROMOS).

### Objective
- Introduction to classical (atomic/molecular) computer simulation of (bio)molecular systems, development of skills to carry out and interpret these simulations.

### Literature
- See: www.csms.ethz.ch/education/CSBMS

### Prerequisites / notice
- Since the exercises on the computer do convey and test essentially different skills than those being conveyed during the lectures and tested at the oral exam, the results of the exercises are taken into account when evaluating the results of the exam (learning component, possible bonus of up to 0.25 points on the exam mark).

For more information about the lecture: www.csms.ethz.ch/education/CSBMS

### Advanced Quantum Chemistry

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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>529-0003-01L</td>
<td>Advanced Quantum Chemistry</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>M. Reiher, A. Baiardi</td>
</tr>
</tbody>
</table>

### Abstract
- Advanced, but fundamental topics central to the understanding of theory in chemistry and for solving actual chemical problems with a computer.
- Examples are:
  - Operators derived from principles of relativistic quantum mechanics
  - Relativistic effects + methods of relativistic quantum chemistry
  - Open-shell molecules + spin-density functional theory
  - New electron-correlation theories

### Literature
Objective

The aim of the course is to provide an in-depth knowledge of theory and method development in theoretical chemistry. It will be shown that this is necessary in order to be able to solve actual chemical problems on a computer with quantum chemical methods.

The relativistic re-derivation of all concepts known from (nonrelativistic) quantum mechanics and quantum-chemistry lectures will finally explain the form of all operators in the molecular Hamiltonian - usually postulated rather than deduced. From this, we derive operators needed for molecular spectroscopy (like those required by magnetic resonance spectroscopy). Implications of other assumptions in standard non-relativistic quantum chemistry shall be analyzed and understood, too. Examples are the Born-Oppenheimer approximation and the expansion of the electronic wave function in a set of pre-defined many-electron basis functions (Slater determinants). Overcoming these concepts, which are so natural to the theory of chemistry, will provide deeper insights into many-particle quantum mechanics. Also revisiting the workhorse of quantum chemistry, namely density functional theory, with an emphasis on open-shell electronic structures (radicals, transition-metal complexes) will contribute to this endeavor. It will be shown how these insights allow us to make more accurate predictions in chemistry in practice - at the frontier of research in theoretical chemistry.

Content

1) Introductory lecture: basics of quantum mechanics and quantum chemistry
2) Einstein's special theory of relativity and the (classical) electromagnetic interaction of two charged particles
3) Klein-Gordon and Dirac equation; the Dirac hydrogen atom
4) Numerical methods based on the Dirac-Fock-Coulomb Hamiltonian, two-component and scalar relativistic Hamiltonians
5) Response theory and molecular properties, derivation of property operators, Breit-Pauli-Hamiltonian
6) Relativistic effects in chemistry and the emergence of spin
7) Spin in density functional theory
8) New electron-correlation theories: Tensor network and matrix product states, the density matrix renormalization group
9) Quantum chemistry without the Born-Oppenheimer approximation

Lecture notes

A set of detailed lecture notes will be provided, which will cover the whole course.

Literature

2) F. Schwabl: Quantenmechanik für Fortgeschrittene (QM II), Springer-Verlag, 1997 [english version available: F. Schwabl, Advanced Quantum Mechanics]
3) R. McWeeny: Methods of Molecular Quantum Mechanics, Academic Press, 1992

Note also the standard textbooks:
A) Szabo, N.S. Ostlund, Verlag, Dover Publications
B) I. N. Levine, Quantum Chemistry, Pearson

Prerequisites / notice

Strongly recommended (preparatory) courses are: quantum mechanics and quantum chemistry

401-5940-00L Seminar in Chemistry for CSE W 4 credits 2S P. H. Hünenberger, M. Reiher

Abstract

The student will carry out a literature study on a topic of his or her liking (suggested by or in agreement with the supervisor) in the area of computer simulation in chemistry (Prof. Hünenberger) or of quantum chemistry (Prof. Reiher), the results of which are to be presented both orally and in written form.

For more information:
http://www.csms.ethz.ch/education/CSE_seminar.html

Fluid Dynamics

One of the course units
151-0103-00L Fluid Dynamics II
151-0109-00L Turbulent Flows

is compulsory.

Students able to follow courses in German are advised to choose 151-0103-00L Fluid Dynamics II.

Number Title Type ECTS Hours Lecturers

<table>
<thead>
<tr>
<th>151-0103-00L</th>
<th>Fluid Dynamics II</th>
<th>O</th>
<th>3 credits</th>
<th>2V+1U</th>
<th>P. Jenny</th>
</tr>
</thead>
</table>

Abstract


Objective

Explore the basic knowledge of fluid dynamics.

Content


Lecture notes

Lecture notes are available (in German). (See also info on literature below.)

Literature

Relevant chapters (corresponding to lecture notes) from the textbook


Prerequisites / notice

Analysis III, Knowledge of Fluid Dynamics I, thermodynamics of ideal gas
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods are being used in a variety of applications including wall bounded turbulent flows, turbulence, and turbulent free shear flows. The course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the qualitative and quantitative description of turbulence. Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling.


Lecture notes are available online. Lecture notes are available after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites: Analysis, linear algebra and a basic course in differential equations.

- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

The course provides an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course). The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

Abstract
- Laminar and turbulent flows, instability and origin of turbulence - Statistical description: averaging, turbulent energy, dissipation, closure problem - Scalings. Homogeneous isotropic turbulence, correlations, Fourier representation, energy spectrum - Free turbulence: wake, jet, mixing layer - Wall turbulence: Channel and boundary layer - Computation and modelling of turbulent flows

Objective
Basic physical phenomena of turbulent flows, quantitative and statistical description, basic and averaged equations, principles of turbulent flow computation and elements of turbulence modelling.

Content
- Properties of laminar, transitional and turbulent flows.
- Origin and control of turbulence. Instability and transition.
- Statistical description, averaging, equations for mean and fluctuating quantities, closure problem.
- Scalings, homogeneous isotropic turbulence, energy spectrum.
- Turbulent free shear flows. Jet, wake, mixing layer.
- Wall-bounded turbulent flows.
- Turbulent flow computation and modeling.

Lecture notes
Lecture notes are available online. Lecture notes are available after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites:
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Language: German on request.

Literature

151-0532-00L Nonlinear Dynamics and Chaos I

W 4 credits 2V+2U G. Haller

Abstract
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-autonomous dynamical systems; chaotic dynamics.

Objective
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by differential equations or discrete maps. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and biology. A more advanced Part II of this class is offered every other year.

Content
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes during the lecture.

Prerequisites / notice
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Language: German on request.

Exam: two-hour written exam in English.

- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

151-0105-00L Quantitative Flow Visualization

W 4 credits 3G

T. Rösgen

Abstract
The course provides an introduction to digital image analysis in modern flow diagnostics. Different techniques which are discussed include image velocimetry, laser induced fluorescence, liquid crystal thermography and interferometry. The physical foundations and measurement configurations are explained. Image analysis algorithms are presented in detail and programmed during the exercises.

Objective
Understanding of hardware and software requirements and solutions. Development of basic programming skills for (generic) imaging applications.

Content
Fundamentals of optics, flow visualization and electronic image acquisition. Frequently used image processing techniques (filtering, correlation processing, FFTs, color space transforms). Image Velocimetry (tracking, pattern matching, Doppler imaging). Surface pressure and temperature measurements (fluorescent paints, liquid crystal imaging, infrared thermography). Laser induced fluorescence. (Digital) Schlieren techniques, phase contrast imaging, interferometry, phase unwrapping. Wall shear and heat transfer measurements. Pattern recognition and feature extraction, proper orthogonal decomposition.

Lecture notes
Handouts will be made available.

Prerequisites / notice
- Prerequisites: Fluidodynamics I, Numerical Mathematics, programming skills.
- Language: German on request.

Exam: two-hour written exam in English.

- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due dates.

151-0213-00L Fluid Dynamics with the Lattice Boltzmann Method

W 4 credits 3G

I. Karlin

Abstract
The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

Objective
Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.
Content

The course builds upon three parts:

I. Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II. Theoretical basis of statistical mechanics and kinetic equations.
III. Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   Particle’s distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation;
   Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   Lattice Boltzmann simulations of turbulent flows;
   numerical stability and accuracy.

5. Microflow:
   Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   Relativistic fluid dynamics; flows with phase transitions.

Lecture notes

Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

401-5950-00L Seminar in Fluid Dynamics for CSE ■ W 4 credits 2S P. Jenny, T. Rösgen

Abstract

Enlarged knowledge and practical abilities in fundamentals and applications of Computational Fluid Dynamics

Objective

Enlarged knowledge and practical abilities in fundamentals and applications of Computational Fluid Dynamics

Prerequisites / notice

Contact Prof. P. Jenny or Prof. T. Rösgen before the beginning of the semester

Systems and Control

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0103-00L</td>
<td>Control Systems</td>
<td>W</td>
<td>6</td>
<td>2V+2U</td>
<td>F. Dörfler</td>
</tr>
<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Signal and Systems Theory II.</td>
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</tr>
</tbody>
</table>

| 227-0225-00L | Linear System Theory          | W    | 6    | 5G    | A. Iannelli         |
| Abstract      | The class is intended to provide a comprehensive overview of the theory of linear dynamical systems, stability analysis, and their use in control and estimation. The focus is on the mathematics behind the physical properties of these systems and on understanding and constructing proofs of properties of linear control systems. |
| Objective     | Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems. - Proof techniques and practices. - Linear spaces, normed linear spaces and Hilbert spaces. - Ordinary differential equations, existence and uniqueness of solutions. - Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case. - Controllability and observability, duality. Time invariant systems treated as a special case. - Stability and stabilization, observers, state and output feedback, separation principle. |
| Content       | - MATLAB is used for system analysis and simulation. |
| Lecture notes | Available on the course Moodle platform. |
| Prerequisites / notice | Sufficient mathematical maturity, in particular in linear algebra, analysis. |
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can master the basics of signals and systems. Apply this knowledge to problems in the homework assignments and programming exercises.

R. D'Andrea

Advanced Machine Learning

### Robotics

**Only one of the two course units**

- 263-5902-00L Computer Vision resp. 227-0447-00L Image Analysis and Computer Vision

may be recognised for credits. More precisely, it is also not allowed to have recognised one course unit for the Bachelor's and the other course unit for the Master's degree.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
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<tbody>
<tr>
<td>151-0601-00L</td>
<td>Theory of Robotics and Mechatronics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>P. Korba, S. Stoeter</td>
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<tr>
<td>252-0535-00L</td>
<td>Advanced Machine Learning</td>
<td>W</td>
<td>10</td>
<td>3V+2U+4A</td>
<td>J. M. Buhmann, C. Cotrini Jimenez</td>
</tr>
</tbody>
</table>

**Abstract**

- Theory of Robotics and Mechatronics
  - This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

- Advanced Machine Learning
  - Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

- Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

- Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

- The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

- Topics covered in the lecture include:
  - Fundamentals:
    - What is data?
    - Bayesian Learning
    - Computational learning theory
  - Supervised learning:
    - Ensembles: Bagging and Boosting
    - Max Margin methods
    - Neural networks
  - Unsupervised learning:
    - Dimensionality reduction techniques
    - Clustering
    - Mixture Models
    - Non-parametric density estimation
  - Learning Dynamical Systems

**Lecture notes**

- No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

The course is designed for graduate students.

Topics covered:
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Solid basic knowledge in statistics, algorithms and programming.

The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

The course is designed for graduate students.

The main concepts and techniques will be studied in depth and practical algorithms and approaches will be discussed and explored through the exercises.

The objectives of this course are:
1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, motion extraction and tracking, 3D data extraction. Invariant features. Specific object recognition and object class recognition. Deep learning and Convolutional Neural Networks.

Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.

This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.

The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.

Course material Script, computer demonstrations, exercises and problem solutions
We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

**Dynamic Programming and Optimal Control**

**Objective**
Covers the fundamental concepts of Dynamic Programming & Optimal Control.

**Content**
Dynamic Programming Algorithm; Deterministic Systems and Shortest Path Problems; Infinite Horizon Problems, Bellman Equation; Deterministic Continuous-Time Optimal Control.

**Literature**

**Prerequisites / notice**
Requirements: Knowledge of advanced calculus, introductory probability theory, and matrix-vector algebra.

**Robot Dynamics**

**Objective**
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

**Content**
The course consists of three parts: First, we will refresh and deepen the student's knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

**Prerequisites / notice**
The contents of the following ETH Bachelor lectures or equivalents are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

**Seminar in Robotics for CSE**

**Objective**
The students are familiar with the challenges of the fascinating and interdisciplinary field of Robotics and Mechatronics. They are introduced in the basics of independent non-experimental scientific research and are able to summarize and to present the results efficiently.

**Content**
This 4 ECTS course requires each student to discuss a study plan with the lecturer and select minimum 10 relevant scientific publications to read through, or attend 5-10 lectures of the public robotics oriented seminars (e.g. Public robotics seminars such as the IRIS's Robotics Seminars and BI/RONZ lectures, for example).

**Prerequisites / notice**
The contents of the following ETH Bachelor lectures or equivalent are assumed to be known: Mechanics and Dynamics, Control, Basics in Fluid Dynamics.

**Introduction to Computational Physics**

This course offers an introduction to computer simulation methods for physics problems and their implementation on PCs and super computers. The covered topics include classical equations of motion, partial differential equations (wave equation, diffusion equation, Maxwell's equations), Monte Carlo simulations, percolation, phase transitions, and N-Body problems.

Students learn to apply the following methods: Random number generators, Determination of percolation critical exponents, numerical solution of problems from classical mechanics and electrodynamics, canonical Monte-Carlo simulations to numerically analyze magnetic systems. Students also learn how to implement their own numerical frameworks in Julia and how to use existing libraries to solve physical problems. In addition, students learn to distinguish between different numerical methods to apply them to solve a given physical problem. Introduction to computer simulation methods for physics problems. Models from classical mechanics, electrodynamics and statistical mechanics as well as some interdisciplinary applications are used to introduce modern programming methods for numerical simulations using Julia. Furthermore, an overview of existing software libraries for numerical simulations is presented.

**Lecture notes**
Lecture notes and slides are available online and will be distributed if desired.

**Literature**
Literature recommendations and references are included in the lecture notes.

**Prerequisites / notice**
Lecture and exercise lessons in English, exams in German or in English.

**Quantum Mechanics I**

**Objective**
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum addition, EPR paradox, Schrödinger and Heisenberg picture).

Applications: simple potentials in wave mechanics, scattering and resonance, harmonic oscillator, hydrogen atom, and perturbation theory.

**Content**
Introduction to single-particle quantum mechanics. Familiarity with basic ideas and concepts (quantisation, operator formalism, symmetries, angular momentum addition, perturbation theory) and generic examples and applications (bound states, tunneling, hydrogen atom, harmonic oscillator); Ability to solve simple problems.

**Literature**
Q. Baym, Lectures on Quantum Mechanics
E. Merzbacher, Quantum Mechanics
L. I. Schiff, Quantum Mechanics
R. Feynman and A.R. Hibbs, Quantum Mechanics and Path Integrals
J.J. Sakurai: Modern Quantum Mechanics
A. Messiah: Quantum Mechanics I
S. Weinberg: Lectures on Quantum Mechanics
Quantum Information Theory

Abstract
The goal of this course is to introduce the concepts and methods of quantum information theory. It starts with an introduction to the mathematical theory of quantum systems and then discusses the basic information-theoretic aspects of quantum mechanics. Further topics include applications such as quantum cryptography and quantum coding theory.

Objective
By the end of the course students are able to explain the basic mathematical formalism (e.g. states, channels) and the tools (e.g. entropy, distinguishability) of quantum information theory. They are able to adapt and apply these concepts and methods to analytically solve quantum information-processing problems primarily related to communication and cryptography.

Content
Mathematical formulation of quantum theory: entanglement, density operators, quantum channels and their representations. Basic tools of quantum information theory: distinguishability of states and channels, formulation as semidefinite programs, entropy and its properties. Applications of the concepts and tools: communication of classical or quantum information over noisy channels, quantitative uncertainty relations, randomness generation, entanglement distillation, security of quantum cryptography.

Lecture notes
Distributed via moodle.

Literature
Nielsen and Chuang, Quantum Information and Computation
Preskill, Lecture Notes on Quantum Computation
Wildie, Quantum Information Theory
Watrous, The Theory of Quantum Information

Particle Accelerator Physics and Modeling I

Abstract
This is the first of two courses, introducing particle accelerators from a theoretical point of view and covers state-of-the-art modelling techniques.

Objective
You understand the building blocks of particle accelerators. Modern analysis tools allows you to model state-of-the-art particle accelerators. In some of the exercises you will be confronted with next generation machines. We will develop a Python (or Julia) simulation tool (pyAcceLEGOrator or jAcceLEGOrator) that reflects the theory from the lecture.

Content
Here is the rough plan of the topics, however the actual pace may vary relative to this plan.

- Recap of Relativistic Classical Mechanics and Electrodynamics
- Building Blocks of Particle Accelerators
- Lie Algebraic Structure of Classical Mechanics and Application to Particle Accelerators
- Symplectic Maps & Analysis of Maps
- Symplectic Particle Tracking
- Collective Effects
- Linear & Circular Accelerators

Lecture notes
Lecture notes

Physics, Computational Science (RW) at BSc. Level

Seminar in Physics for CSE

Abstract
In this seminar, the students present a talk on an advanced topic in modern theoretical or computational physics. An implementation of an advanced algorithm can also be presented.

Objective
To teach students the topics of current interest in computational and theoretical physics.

Computational Finance

Mathematical Foundations for Finance

Abstract
First introduction to main modelling ideas and mathematical tools from mathematical finance

Objective
This course gives a first introduction to the main modelling ideas and mathematical tools from mathematical finance. It mainly aims at non-mathematicians who need an introduction to the main tools from stochastics used in mathematical finance. However, mathematicians who want to learn some basic modelling ideas and concepts for quantitative finance (before continuing with a more advanced course) may also find this of interest. The main emphasis will be on ideas, but important results will be given with (sometimes partial) proofs.

Content
Topics to be covered include
- financial market models in finite discrete time
- absence of arbitrage and martingale measures
- valuation and hedging in complete markets
- basics about Brownian motion
- stochastic integration
- stochastic calculus: Itô's formula, Girsanov transformation, Itô's representation theorem
- Black-Scholes formula

Lecture notes
Lecture notes will be sold at the beginning of the course.
Lecture notes will be sold at the beginning of the course. Additional (background) references are given there.

Prerequisites: Results and facts from probability theory as in the book "Probability Essentials" by J. Jacod and P. Protter will be used freely. Especially participants without a direct mathematics background are strongly advised to familiarise themselves with those tools before (or very quickly during) the course. (A possible alternative to the above English textbook are the (German) lecture notes for the standard course "Wahrscheinlichkeitslehre").

For those who are not sure about their background, we suggest to look at the exercises in Chapters 8, 9, 22-25, 28 of the Jacod/Protter book. If these pose problems, you will have a hard time during the course. So be prepared.

**Abstract**

Course on numerical approximations of stochastic ordinary differential equations driven by Wiener processes. These equations have several applications, for example in financial option valuation. This course also contains an introduction to random number generation and Monte Carlo methods for random variables.

**Objective**

The aim of this course is to enable the students to carry out simulations and their mathematical convergence analysis for stochastic models originating from applications such as mathematical finance. For this the course teaches a decent knowledge of the different numerical methods, their underlying ideas, convergence properties and implementation issues.

**Content**

- Generation of random numbers
- Monte Carlo methods for the numerical integration of random variables
- Stochastic processes and Brownian motion
- Stochastic ordinary differential equations (SODEs)
- Numerical approximations of SODEs
- Applications to computational finance: Option valuation

**Lecture notes**

There will be English, typed lecture notes for registered participants in the course.

**Literature**


**Prerequisites / notice**

Mandatory: Probability and measure theory, basic numerical analysis and basics of MATLAB/Python programming.

a) mandatory courses:
- Elementary Probability
- Probability Theory I.

b) recommended courses:
- Stochastic Processes.

Objective

The course explains the key concepts and mechanisms of financial economics, their depth and then stresses how and why the theories and models fail and how this is impacting investment strategies and even a global view of citizenship, given the present developing crises in the US since 2007 and in Europe since 2010.

- Development of the concepts and tools to understand these risks and master them.
- Working knowledge of the main concepts and tools in finance (Portfolio theory, asset pricing, options, real options, bonds, interest rates, inflation, exchange rates)
- Strong emphasis on challenging assumptions and developing a systemic understanding of financial markets and their many dimensional risks

Content

1- The Financial Crises: what is really happening? Historical perspective and what can be expected in the next decade(s). Bubbles and crashes. The illusion of the perpetual money machine.

2- Risks in financial markets
- What is risk?
- Measuring risks of financial assets
- Introduction to three different concepts of probability
- History of financial markets, diversification, market risks

3- Introduction to financial risks and its management.
- Relationship between risk and return
- Portfolio theory: the concept of diversification and optimal allocation
- How to price assets: the Capital Asset Pricing Model
- How to price assets: the Arbitrage Pricing Theory, the factor models and beyond

4- Financial markets: role and efficiency
- What is an efficient market?
- Financial markets as valuation engines: exogeneity versus endogeneity (reflexivity)
- Deviations from efficiency, puzzles and anomalies in the financial markets
- Financial bubbles, crashes, systemic instabilities

5- An introduction to Options and derivatives
- Calls, Puts and Shares and other derivatives
- Financial alchemy with options (options are building blocs of any possible cash flow)
- Determination of option value; concept of risk hedging

6- Valuation and using options
- A first simple option valuation model
- The Binomial method for valuing options
- The Black-scholes model and formula
- Practical examples and implementation
- Realized prices deviate from these theories: volatility smile and real option trading
- How to imperfectly hedge with real markets?

7- Real options
- The value of follow-on investment opportunities
- The timing option
- The abandonment option
- Flexible production
- Conceptual aspects and extensions

8- Government bonds and their valuation
- Relationship between bonds and interest rates
- Real and nominal rates of interest
- Term structure and Yields to maturity
- Explaining the term structure
- Different models of the term structure

9- Managing international risks
- The foreign exchange market
- Relations between exchanges rates and interest rates, inflation, and other economic variables
- Hedging currency risks
- Currency speculation
- Exchange risk and international investment decisions

Lecture notes

Lecture slides will be available on the site of the lecture

Literature

Corporate finance
Brealey / Myers / Allen
Eight edition

+ Additional paper reading provided during the lectures

Prerequisites / notice

none

Seminar in Computational Finance for CSE
4 credits
J. Teichmann

Content

We aim to comprehend recent and exciting research on the nature of stochastic volatility: an extensive econometric research [4] lead to new insights on stochastic volatility, in particular that very rough fractional processes of Hurst index about 0.1 actually provide very attractive models. Also from the point of view of pricing [1] and microfoundations [2] these models are very convincing.

More precisely each student is expected to work on one specified task consisting of a theoretical part and an implementation with financial data, whose results should be presented in a 45 minutes presentation.
The path of an analog signal in the transmitter to the digital world in a communication link and back to the analog world at the receiver is a basic knowledge of the fundamental equations and effects of electromagnetics, mechanics, and heat transfer. Knowledge of the main types of materials, nonlinear and resonant effects, and antenna applications is discussed.

## Objective
You can describe wave propagation in classical and nonclassical materials and know the fundamental solutions. You know how waves interact with matter and about nonlinear and resonant effects. You can apply the acquired knowledge in scattering, waveguiding, radiation, and antenna problems.

## Content
The lecture covers the following topics:
- Generic time-harmonic electromagnetic fields
- Fundamental solutions of the wave equation
- Wave propagation in various types of materials
- Interaction of waves with matter
- Nonlinear effects
- Resonant effects
- Applications like scattering, waveguiding, radiation
- Radio frequency and optical antennas

## Lecture notes
Lecture notes and slides will be handed out during the lectures.

## Prerequisites / notice
Requirements: sound understanding of stochastic concepts and of concepts of mathematical Finance, ability to implement econometric or simulation routines in MATLAB.

### Electromagnetics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0110-00L</td>
<td>Electromagnetic Waves: Materials, Effects, and Antennas</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U</td>
<td>U. Koch</td>
</tr>
<tr>
<td>227-2037-00L</td>
<td>Physical Modelling and Simulation</td>
<td>W</td>
<td>6 credits</td>
<td>4G</td>
<td>J. Smajic</td>
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<tr>
<td>227-0301-00L</td>
<td>Optical Communication Fundamentals</td>
<td>W</td>
<td>6 credits</td>
<td>2V+1U+1P</td>
<td>J. Leuthold</td>
</tr>
<tr>
<td>401-4785-00L</td>
<td>Mathematical and Computational Methods in Photonics</td>
<td>W</td>
<td>8 credits</td>
<td>4G</td>
<td>H. Ammarri</td>
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</tbody>
</table>

**Literature**


**Prerequisites / notice**

- Remark: the lecture succeeds «Advanced Electromagnetic Waves» and reorients itself to materials, effects, and applications with waves.

**Lecture notes**

- Lecture notes are handed out.

**Literature**

- Govind P. Agrawal; "Fiber-Optic Communication Systems"; Wiley, 2010

**Prerequisites / notice**


**Number**

- 401-4785-00L

**Abstract**

The aim of this course is to review new and fundamental mathematical tools, computational approaches, and inversion and optimal design methods used to address challenging problems in nanophotonics. The emphasis will be on analyzing plasmon resonant nanoparticles, super-focusing & super-resolution of electromagnetic waves, photonic crystals, electromagnetic cloaking, metamaterials, and metasurfaces.
The field of photonics encompasses the fundamental science of light propagation and interactions in complex structures, and its technological applications.

The recent advances in nanoscience present great challenges for the applied and computational mathematics community. In nanophotonics, the aim is to control, manipulate, reshape, guide, and focus electromagnetic waves at nanometer length scales, beyond the resolution limit. In particular, one wants to break the resolution limit by reducing the focal spot and confine light to length scales that are significantly smaller than half the wavelength.

Interactions between the field of photonics and mathematics has led to the emergence of a multitude of new and unique solutions in which today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. Light can be used for detection and measurement in a fast, sensitive and accurate manner, and thus photonics possesses a unique potential to revolutionize healthcare.

Light-based technologies can be used effectively for the very early detection of diseases, with non-invasive imaging techniques or point-of-care applications. They are also instrumental in the analysis of processes at the molecular level, giving a greater understanding of the origin of diseases, and hence allowing prevention along with new treatments. Photonic technologies also play a major role in addressing the needs of our ageing society: from pace-makers to synthetic bones, and from endoscopes to the micro-cameras used in in-vivo processes. Furthermore, photonics are also used in advanced lighting technology, and in improving energy efficiency and quality. By using photonic media to control waves across a wide band of wavelengths, we have an unprecedented ability to fabricate new materials with specific microstructures.

The main objective in this course is to report on the use of sophisticated mathematics in diffractive optics, plasmonics, super-resolution, photonic crystals, and metamaterials for electromagnetic invisibility and cloaking. The book merges highly nontrivial multi-mathematics in order to make a breakthrough in the field of mathematical modelling, imaging, and optimal design of optical nanodevices and nanostructures capable of light enhancement, and of the focusing and guiding of light at a subwavelength scale. We demonstrate the power of layer potential techniques in solving challenging problems in photonics, when they are combined with asymptotic analysis and the elegant theory of Gohberg and Sigal on meromorphic operator-valued functions.

In this course we shall consider both analytical and computational matters in photonics. The issues we consider lead to the investigation of fundamental problems in various branches of mathematics. These include asymptotic analysis, spectral analysis, mathematical imaging, optimal design, stochastic modelling, and analysis of wave propagation phenomena. On the other hand, deriving mathematical foundations, and new and efficient computational frameworks and tools in photonics, requires a deep understanding of the different scales in the wave propagation problem, an accurate mathematical modelling of the nanodevices, and fine analysis of complex wave propagation phenomena. An emphasis is put on mathematically analyzing plasmon resonant nanoparticles, diffractive optics, photonic crystals, super-resolution, and metamaterials.

Objectives:

- Knowledge of the fundamentals of electromagnetic theory, development and application of numerical methods for solving Maxwell equations, analysis and optimal design of electromagnetic structures
- In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

### Geophysics

**Recommended combinations:**

- Subject 2 + Subject 5 + Subject 6 + Subject 7
- Subject 2 + Subject 4 + Subject 5 + Subject 6 + Subject 8
- Subject 2 + Subject 5 + Subject 6 + (Subject 1 or Subject 3)

#### Geophysics: Subject 1

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<tr>
<th>Number</th>
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<tr>
<td>651-4007-00L</td>
<td>Continuum Mechanics</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>T. Gerya</td>
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</table>

Abstract

In this course, students learn crucial partial differential equations (conservation laws) that are applicable to any continuum including the Earth's mantle, core, atmosphere and ocean. The course will provide step-by-step introduction into the mathematical structure, physical meaning and analytical solutions of the equations. The course has a particular focus on solid Earth applications.

Objective

The goal of this course is to learn and understand few principal partial differential equations (conservation laws) that are applicable for analysing and modelling of any continuum including the Earth's mantle, core, atmosphere and ocean. By the end of the course, students should be able to write, explain and analyse the equations and apply them for simple analytical cases. Numerical solving of these equations will be discussed in the Numerical Modelling I and II course running in parallel.
A provisional week-by-week schedule (subject to change) is as follows:

Weeks 1, 2: The continuity equation
Exercise: Computing the divergence of velocity field.

Weeks 3, 4: Density and gravity
Exercises: Computing density, thermal expansion and compressibility from an equation of state. Derivation of gravitational acceleration and its divergence from gravitational potential.

Weeks 5, 6: Stress and strain
Exercises: Analysing strain rate tensor for solid body rotation. Computing stress invariants

Weeks 7, 8: The momentum equation

Week 9: Viscous rheology of rocks
Theory: Solid-state creep of minerals and rocks as the major mechanism of deformation of the Earth's interior. Dislocation and diffusion creep mechanisms. Rheological equations for minerals and rocks. Effective viscosity and its dependence on temperature, pressure and strain rate. Formulation of the effective viscosity from empirical flow laws.
Exercise: Deriving viscous rheological equations for computing effective viscosities from empirical flow laws.

Weeks 10, 11: The heat conservation equation
Exercises: Computing heat fluxes. Deriving equation for steady state temperature profile in a magmatic channel.

Week 12, 13: Elasticity and plasticity
Exercise: Compute viscoelastic stress evolution.


GRADING will be based on homeworks (1/3) and oral exam (2/3).

Lecture notes
Script and Exam questions are available by request tgerya@ethz.ch

Literature

Geophysics: Subject 2

Numerical Modelling I and II: Theory and Applications

In this 13-week sequence, students learn how to write programs from scratch to solve partial differential equations that are useful for Earth science applications. Programming will be done in MATLAB and will use the finite-difference method and marker-in-cell technique. The course will emphasise a hands-on learning approach rather than extensive theory.

The goal of this course is for students to learn how to program numerical applications from scratch. By the end of the course, students should be able to write state-of-the-art MATLAB codes that solve systems of partial-differential equations relevant to Earth and Planetary Science applications using finite-difference method and marker-in-cell technique. Applications include Poisson equation, buoyancy-driven variable viscosity flow, heat diffusion and advection, and state-of-the-art thermomechanical code programming. The emphasis will be on commonality, i.e., using a similar approach to solve different applications, and modularity, i.e., re-use of code in different programs. The course will emphasise a hands-on learning approach rather than extensive theory, and will begin with an introduction to programming in MATLAB.
This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience.

This course provides an overview on the most widely used seismological methods to image the Earth's interior with a focus on crustal and upper-mantle structures. Topics include controlled source methods such as refraction and wide-angle reflection, as well as passive body-wave and surface-wave based methods. The course will discuss the strengths and weaknesses of each method.

Week 1: Introduction to the finite difference approximation to differential equations. Introduction to programming in Matlab. Solving of 1D Poisson equation.


Week 3: Solving momentum and continuity equations in case of constant viscosity using stream function/vorticity formulation. Solving momentum and continuity equations in case of constant viscosity using pressure-velocity formulation with staggered grid.


Week 5: Conservative finite differences for the momentum equation. "Free slip" and "no slip" boundary conditions. Solving momentum and continuity equations in case of variable viscosity using pressure-velocity formulation with staggered grid.


Week 7: Advecting in 2-D with Marker-in-cell method. Combining flow calculation and advection for buoyancy driven flow.


Week 9: Solving 2D heat conservation equation in case of constant thermal conductivity with explicit and implicit approaches.

Week 10: Solving 2D heat conservation equation in case of variable thermal conductivity with implicit approach. Temperature advection with markers. Creating thermomechanical code by combining mechanical solution for 2D buoyancy driven flow with heat diffusion and advection based on marker-in-cell approach.

Week 11: Implementation of radioactive, adiabatic and shear heating to the thermomechanical code.

Week 12: Programming of solution of coupled solid-fluid momentum and continuity equations for the case of melt percolation in a rising mantle plume.


GRADING will be based on weekly programming homeworks (50%) and a term project (50%) to develop an application of their choice to a more advanced level.

Literature


Objective

Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to earth science.

Lecture notes

See http://jupiter.ethz.ch/~pj/FORTRAN/FortranClass.html

Taught competencies

Domain A - Subject-specific Competencies
- Techniques and Technologies
  - assessed

Domain B - Method-specific Competencies
- Media and Digital Technologies
  - assessed
- Problem-solving
  - assessed

ünün Geophysics: Seminar

Number Title Type ECTS Hours Lecturers
401-5880-00L Seminar in Geophysics for CSE W 4 credits 2S T. Gerya, P. Tackley

Abstract

The seminar in geophysics for CSE is a work on a small research project for 4 credit points. The project can be supervised and graded by any member of the Institute of Geophysics with doctoral degree.

Objective

Students will learn modern quantitative geophysical research by conducting a small original project on a relevant subject. Students should find a project of interest by contacting potential supervisors from the Institute of Geophysics and agree on the content and timing of the project. At the end of the project, a written report of free format should be submitted by the student, which is then graded by the supervisor.

Lecture notes

No script

Literature

Relevant literature should be provided by the project supervisor.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
  - assessed
- Techniques and Technologies
  - assessed

Domain B - Method-specific Competencies
- Analytical Competencies
  - assessed
- Decision-making
  - assessed
- Media and Digital Technologies
  - not assessed
- Problem-solving
  - assessed
- Project Management
  - assessed

Domain C - Social Competencies
- Communication
  - assessed
- Cooperation and Teamwork
  - assessed
- Customer Orientation
  - not assessed
- Leadership and Responsibility
  - not assessed
- Self-presentation and Social Influence
  - not assessed
- Sensitivity to Diversity
  - not assessed
- Negotiation
  - not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility
  - not assessed
- Creative Thinking
  - assessed
- Critical Thinking
  - assessed
- Integrity and Work Ethics
  - not assessed
- Self-awareness and Self-reflection
  - not assessed
- Self-direction and Self-management
  - assessed

Biology

Number Title Type ECTS Hours Lecturers
636-0007-00L Computational Systems Biology W 6 credits 3V+2U J. Stelling

Abstract

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modelling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content

Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological networks with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) quantitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes

http://www.csb.ethz.ch/education/lectures.html


636-0017-00L Computational Biology W 6 credits 3G+2A T. Vaughan

Abstract

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

The course consists of four parts. We first introduce modern genetic sequencing technology, and algorithms to obtain sequence alignments from the output of the sequencers. We then present methods for direct alignment analysis using approaches such as BLAST and GWAS. Second, we introduce mechanisms and concepts of molecular evolution, i.e. we discuss how genetic sequences change over time. Third, we employ evolutionary concepts to infer ancestral relationships between organisms based on their genetic sequences, i.e. we discuss methods to infer genealogies and phylogenies. Lastly, we introduce the field of phylocomics, the aim of which is to understand and quantify population dynamic processes (such as transmission in epidemiology or speciation & extinction in macroevolution) based on a phylogeny. Throughout the class, the models and methods are illustrated on different datasets giving insight into the epidemiology and evolution of a range of infectious diseases (e.g. HIV, HCV, influenza, Ebola). Applications of the methods to the field of macroevolution provide insight into the evolution and ecology of different species clades. Students will be trained in the algorithms and their application both on paper and in silico as part of the exercises.

Lecture notes
Lecture slides will be available on moodle.

Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (cumulative continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course „Introduction to Programming“, which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date.

For the Zurich-based students without R experience, we recommend the R course http://www.vvz.ethz.ch/Vorlesungsverzeichnis/lehreinheit?semkey=2018W&ansicht=KATALOGDATEN&lehreinheitid=123546&lang=d e, or working through the script provided as part of this R course.

### 636-0706-00L Spatio-Temporal Modelling in Biology

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Objective</td>
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<tr>
<td>Students will learn state-of-the-art approaches to modelling spatial effects in dynamical biological systems. The course provides an introduction to key concepts in developmental biology.</td>
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<table>
<thead>
<tr>
<th>Content</th>
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<tbody>
<tr>
<td>1. Introduction to Modelling in Biology</td>
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<td>2. Morphogen Gradients</td>
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<td>3. Dynamical Systems</td>
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<td>4. Cell-cell Signalling (Dr Boareto)</td>
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<td>5. Travelling Waves</td>
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<td>6. Turing Patterns</td>
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<td>7. Chemotaxis</td>
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<td>8. Mathematical Description of Growing Biological Systems</td>
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<td>9. Image-Based Modelling</td>
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<td>10. Tissue Mechanics</td>
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<tr>
<td>11. Cell-based Tissue Simulation Frameworks</td>
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<td>12. Plant Development (Dr Dumont)</td>
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<td>13. Growth Control</td>
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<td>14. Summary</td>
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Lecture notes
All lecture material will be made available online https://www.bsse.ethz.ch/cobi/teaching/636-0706-00L_Spatial_Modelling_in_Biology.html

Literature
The lecture course is not based on any textbook. The following textbooks are related to some of its content. The textbooks may be of interest for further reading, but are not necessary to follow the course:

- Murray, Mathematical Biology, Springer
- Forgacs and Newman, Biological Physics of the Developing Embryo, CUP
- Keener and Sneyd, Mathematical Physiology, Springer
- Fall et al, Computational Cell Biology, Springer
- Szallasi et al, System Modeling in Cellular Biology, MIT Press
- Wolkenhauer, Systems Biology
- Kreyszig, Engineering Mathematics, Wiley

Prerequisites / notice
The course is self-contained. The course assumes no background in biology but a good foundation regarding mathematical and computational techniques.

### 227-0421-00L Deep Learning in Artificial and Biological Neuronal Networks

<table>
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<tr>
<th>Component</th>
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<tr>
<td>Objective</td>
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<tr>
<td>Deep-Learning (DL) a brain-inspired weak for of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. However, DL is far from being understood and investigating learning in biological networks might serve again as a compelling inspiration to think differently about state-of-the-art ANN training methods.</td>
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Autumn Semester 2021
The main goal of this lecture is to provide a comprehensive overview into the learning principles neuronal networks as well as to introduce a diverse skill set (e.g. simulating a spiking neuronal network) that is required to understand learning in large, hierarchical neuronal networks. To achieve this the lectures and exercises will merge ideas, concepts and methods from machine learning and neuroscience. These will include training basic ANNs, simulating spiking neuronal networks as well as being able to read and understand the main ideas presented in today's neuroscience papers.

After this course students will be able to:
- read and understand the main ideas and methods that are presented in today's neuroscience papers
- explain the basic ideas and concepts of plasticity in the mammalian brain
- implement alternative ANN learning algorithms to 'error backpropagation' in order to train deep neuronal networks.
- use a diverse set of ANN regularization methods to improve learning
- simulate spiking neuronal networks that learn simple (e.g. digit classification) tasks in a supervised manner.

Deep-learning a brain-inspired weak form of AI allows training of large artificial neuronal networks (ANNs) that, like humans, can learn real-world tasks such as recognizing objects in images. The origins of deep hierarchical learning can be traced back to early neuroscience research by Hubel and Wiesel in the 1960s, who first described the neuronal processing of visual inputs in the mammalian neocortex. Similar to their neocortical counterparts ANNs seem to learn by interpreting and structuring the data provided by the external world. However, while on specific tasks such as playing (video) games deep ANNs outperform humans (Minh et al, 2015, Silver et al., 2018), ANNs will be outperformed by humans when it comes to recognizing actions in movie data and their ability to act as generalizable problem solvers is still far behind of what the human brain seems to achieve effortlessly. Moreover, biological neuronal networks can learn far more effectively with fewer training examples, they achieve a much higher performance in recognizing complex patterns in time series data (e.g. recognizing actions in movies), they dynamically adapt to new tasks without losing performance and they achieve unmatched performance to detect and integrate out-of-domain data examples (data they have not been trained with). In other words, many of the big challenges and unknowns that have emerged in the field of deep learning over the last years are already mastered exceptionally well by biological neuronal networks in our brain. On the other hand, many facets of typical ANN design and training algorithms seem biologically implausible, such as the non-local weight updates, discrete processing of time, and scalar communication between neurons. Recent evidence suggests that learning in biological systems is the result of the complex interplay of diverse error feedback signaling processes acting at multiple scales, ranging from single synapses to entire networks.

The lecture slides will be provided as a PDF after each lecture. This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation, including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

The participation in the course is subject to the following conditions:
1) The number of participants is limited to 120 students (MSc and PhDs).
2) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.
3) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.
4) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.
5) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.
6) Students must have taken the exam in Deep Learning (263-3210-00L) or have acquired equivalent knowledge.

The course provides an introduction to the functional properties of neurons. Particularly the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. Simple models of computation, learning, and behavior will be presented. Artificial systems (robot, chip) are presented. Understanding computation by neurons and neuronal circuits is one of the great challenges of science. Many different disciplines can contribute their tools and concepts to solving mysteries of neuronal computation. The goal of this introductory course is to introduce the monocultures of physics, maths, computer science, engineering, biology, psychology, and even philosophy and history, to discover the enchantments and challenges that we all face in taking on this major 21st century problem and how each discipline can contribute to discovering solutions.

This advanced level lecture requires some basic background in machine/deep learning. Thus, students are expected to have a basic mathematical foundation including linear algebra, multivariate calculus, and probability. The course is not to be meant as an extended tutorial of how to train deep networks in PyTorch or Tensorflow, although these tools used.

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This course introduces principle concepts, the state-of-the-art and methods used in some major fields of Bioinformatics. Topics include: genomics, metagenomics, network bioinformatics, and imaging. Lectures are accompanied by practical exercises that involve the use of common bioinformatic methods and basic programming.

The course will provide students with theoretical background in the area of genomics, metagenomics, network bioinformatics and imaging. In addition, students will acquire basic skills in applying modern methods that are used in these sub-disciplines of Bioinformatics. Students will be able to access and analyse DNA sequence information, construct and interpret networks that emerge though interactions of e.g. genes/proteins, and extract information based on computer-assisted image data analysis. Students will also be able to assess the ethical implications of access to and generation of new and large amounts of information as they relate to the identifyability of a person and the ownership of data.
When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, this course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

### Content

- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

#### Content

- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

#### Part 3 - Final project

- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

### Prerequisites / notice

Course participants have already acquired basic programming skills in Python and R. Students will bring and work on their own laptop computers, preferentially running the latest versions of Windows or MacOSX.

### Electives

In the 'electives' subcategory, at least two course units must be successfully completed.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
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</table>

### Abstract

This course aims to cover state-of-the-art methods in modern parallel Graphical Processing Unit (GPU) computing, supercomputing and code development with applications to natural sciences and engineering.

When quantitative assessment of physical processes governing natural and engineered systems relies on numerically solving differential equations, fast and accurate solutions require performant algorithms leveraging parallel hardware. The goal of this course is to offer a practical approach to solve systems of differential equations in parallel on GPUs using the Julia language. Julia combines high-level language conciseness to low-level language performance which enables efficient code development.

The course will be taught in a hands-on fashion, putting emphasis on you writing code and completing exercises; lecturing will be kept at a minimum. In a final project you will solve a solid mechanics or fluid dynamics problem of your interest, such as the shallow water equation, the shallow ice equation, acoustic wave propagation, nonlinear diffusion, viscous flow, elastic deformation, viscous or elastic poromechanics, frictional heating, and more. Your Julia GPU application will be hosted on a git-platform and implement modern software development practices.

### Content

- Learn the basics of the Julia language;
- Learn about the diffusion process and how to solve it;
- Understand the practical challenges of parallel and distributed computing: (multi-)GPUs, multi-core CPUs;
- Learn about software development tools: git, version control, continuous integration (CI), unit tests.

#### Part 2 - Developing your own parallel algorithms

- Implement wave propagation (or more advanced physics);
- Apply spatial and temporal discretisation (finite-differences, various time-stepper);
- Implement efficient iterative algorithms;
- Implement shared (on CPU and GPU) and, if time allows, distributed memory parallelisation (multi-GPUs/CPUs);
- Learn about main simulation performance limiters.

#### Part 3 - Final project

- Apply your new skills in a final project;
- Implement advanced physical processes (solid and fluid dynamic - elastic and viscous solutions).

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**Genomics:**
- Genetic variant calling
- Analysis and critical evaluation of genome-wide association studies

**Metagenomics:**
- Reconstruction of microbial genomes
- Microbial community compositional analysis
- Quantitative metagenomics

**Network bioinformatics:**
- Inference of molecular networks
- Use of networks for interpretation of (gen)omics data

**Imaging:**
- High throughput single cell imaging
- Image segmentation

**Automatic analysis of drug effects on single cell suspension (chemotyping)**

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**Prerequisites / notice**

Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

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### Literature

- Digital lecture notes, interactive Julia notebooks, online material.
- Links to relevant literature will be provided during classes.

### Prerequisites / notice

Completed BSc studies. Interest in and basic knowledge of numerics, applied mathematics, and physics/engineering sciences. Basic programming skills (in e.g. Matlab, Python, Julia); advanced programming skills are a plus.

### 151-0709-00L Stochastic Methods for Engineers and Natural Scientists

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>151-0709-00L</td>
<td>Stochastic Methods for Engineers and Natural</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>D. W. Meyer-Massetti</td>
</tr>
</tbody>
</table>

### Abstract

The course provides an introduction into stochastic methods that are applicable for example for the description and modeling of turbulent and subsurface flows. Moreover, mathematical techniques are presented that are used to quantify uncertainty in various engineering applications.

By the end of the course you should be able to mathematically describe random quantities and their effect on physical systems. Moreover, you should be able to develop basic stochastic models of such systems.

- Probability theory, single and multiple random variables, mappings of random variables
- Estimation of statistical moments and probability densities based on data
- Stochastic differential equations, Ito calculus, PDF evolution equations
- Monte Carlo integration with importance and stratified sampling
- Markov-chain Monte Carlo sampling
- Control-variate and multi-level Monte Carlo estimation

All topics are illustrated with engineering applications.

### Lecture notes

Detailed lecture notes will be provided.

### Literature

- Some textbooks related to the material covered in the course:

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**Data:** 14.12.2021 12:41

**Autumn Semester 2021**

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Most problems in engineering are of nonlinear nature. The nonlinearities are caused basically due to the nonlinear material behavior, the interaction of the human user with the digital environment, or the use of augmented reality systems. The goal of the lecture is to provide a deeper knowledge of today’s VR environments that are used in business processes. The technical background, the algorithms, and the applied methods are explained more in detail. Finally, future tasks of VR will be discussed and an outlook on ongoing international research is given.

The goal of the lecture is to provide the students with the fundamentals of the non linear Finite Element Method (FEM). The lecture focuses on the principles of the nonlinear Finite-Element-Method based on explicit and implicit formulations. Typical applications of the nonlinear FEM Program ABAQUS is introduced to investigate real engineering problems. The ability to independently create a virtual model which describes the complex non linear systems will be acquired through accompanying exercises. These will include the Matlab programming of important model components such as constitutive equations. The FEM Program ABAQUS will be introduced to investigate real engineering problems.
### 151-0529-00L Computational Mechanics II: Nonlinear FEA

**Objective**
To be able to address all major sources of non-linearity in theory and numerics, and to apply this knowledge to the solution of relevant problems in solid mechanics.

**Content**
1. Introduction: various sources of nonlinearities and implications for FEA.

**Prerequisites / notice**
Lecture notes will be provided. However, students are encouraged to take their own notes.

**Literature**

### 263-2800-00L Design of Parallel and High-Performance Computing

**Objective**
Understand concurrency paradigms and models from a higher perspective and acquire skills for designing, structuring and developing possibly large parallel high-performance software systems. Become able to distinguish parallelism in problem space and in machine space. Become familiar with important technical concepts and with concurrency folklore.

**Content**
We will cover all aspects of high-performance computing ranging from architecture through programming up to algorithms. We will start with a discussion of caches and cache coherence in practical computer systems. We will dive into parallel programming concepts such as memory models, locks, and lock-free. We will cover performance modeling and parallel design principles as well as basic parallel algorithms.

**Prerequisites / notice**
This class is intended for the Computer Science Masters curriculum. Students must have basic knowledge in programming in C as well as computer science theory. Students should be familiar with the material covered in the ETH computer science first-year courses "Parallele Programmierung (parallel programming)" and "Algorithmen und Datenstrukturen (algorithm and data structures)" or equivalent courses.

### 263-5905-00L Mixed Reality

**Objective**
After attending this course, students will:
1. Understand the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
2. Have a clear understanding on how to build mixed reality apps
3. Have a good overview of state-of-the-art Mixed Reality
4. Be able to critically analyze and assess current research in this area.

**Content**
The course introduces latest mixed reality technology and provides introductory elements for a number of related fields including:
- Computer graphics/vision experience: Students should have taken, at a minimum, Visual Computing. Higher level courses are recommended, such as Introduction to Computer Graphics, 3D Vision, Computer Vision.
-Good programming skills (C# / C++ / Java etc.)
- HoloLens in combination with C# and Unity3D - other platforms are also possible to use, such as tablets and phones.

**Prerequisites / notice**
Prerequisites include:
- Solvers and convergence
- Modeling of tool contact and the influence of friction
- FEM formulations of coupled thermo-mechanical problems
- Implicit and explicit FEM methods
- Element formulations
- Modeling of tool contact and the influence of friction
- Solvers and convergence
- Instability problems
- Fundamentals of continuum mechanics to characterize large plastic deformations
- Elasto-plastic material models
- Lagrange and Euler approaches
- FEM implementation of constitutive equations
- Material properties (hyperelasticity, plasticity), kinematics (large deformations, instability problems) and boundary conditions (contact).

**Literature**
Lecture slides

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Credits</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0529-00L</td>
<td>Computational Mechanics II: Nonlinear FEA</td>
<td>4</td>
<td>2V+2U</td>
<td>L. De Lorenzis</td>
</tr>
<tr>
<td>263-2800-00L</td>
<td>Design of Parallel and High-Performance Computing</td>
<td>9</td>
<td>3V+2U+3A</td>
<td>T. Hoeffler, M. Püschel</td>
</tr>
<tr>
<td>263-5905-00L</td>
<td>Mixed Reality</td>
<td>5</td>
<td>3G+1A</td>
<td>I. Armeni, F. Bogo, M. Pollefeys</td>
</tr>
<tr>
<td>227-0102-00L</td>
<td>Discrete Event Systems</td>
<td>6</td>
<td>4G</td>
<td>R. Jacob, L. Vanbever, R. Wattenhofer</td>
</tr>
</tbody>
</table>

Abstract
This course is concerned with system-level issues of VLSI design and FPGA implementations. Topics include:
- Overview on design methodologies and fabrication depths.
- Levels of abstraction for circuit modeling.
- Organization and configuration of commercial field-programmable components.
- FPGA design flows.
- Dedicated and general purpose architectures compared.
- How to obtain an architecture for a given processing algorithm.
- Meeting throughput, area, and power goals by way of architectural transformations.
- Hardware Description Languages (HDL) and the underlying concepts.
- SystemVerilog
- Register Transfer Level (RTL) synthesis and its limitations.
- Building blocks of digital VLSI circuits.
- Functional verification techniques and their limitations.
- Modular and largely reusable testbenches.
- Assertion-based verification.
- Synchronous versus asynchronous circuits.
- The case for synchronous circuits.
- Periodic events and the Anceau diagram.
- Case studies, ASICs compared to microprocessors, DSPs, and FPGAs.

During the exercises, students learn how to model FPGAs with SystemVerilog. They write testbenches for simulation purposes and synthesize gate-level netlists for FPGAs. Commercial EDA software by leading vendors is being used throughout.

Lecture notes
Textbook and all further documents in English.

Prerequisites / notice
Basics of digital circuits.

Examination:
In written form following the course semester (spring term). Problems are given in English, answers will be accepted in either English oder German.

Further details:
https://iis-students.ee.ethz.ch/lectures/vlsi-i/

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227-0147-10L
VLSI 3: Full-Custom Digital Circuit Design
6 credits
2V+3U
C. Studer, O. Castañeda Fernández

Abstract
This third course in our VLSI series is concerned with full-custom digital integrated circuits. The goals are to learn how to design digital circuits on the schematic, layout, gate, and register-transfer levels. The use of state-of-the-art CAD software (Cadence Virtuoso) in order to simulate, optimize, and characterize digital circuits is another important topic of this course.
Information Theory I

In this course we will deal with modern integrated circuit (IC) manufacturing technology and cover topics such as:

- Nanometer MOSFETs
- Static and dynamic behavior of complementary MOS (CMOS) inverters
- CMOS gate design, sizing, and timing
- Full-custom standard-cell design
- Wire models and parasitics
- Latch and flip-flop circuits
- Gate-level timing analysis and optimization
- Static and dynamic power consumption; low-power techniques
- Alternative logic styles (dynamic logic, pass-transistor logic, etc.)
- Arithmetic and logic circuits
- Fixed-point and floating-point arithmetic
- Memory circuits (ROM, SRAM, and DRAM)
- In- and near-memory processing architectures
- Full-custom accelerator circuits for machine learning

The exercises are concerned with schematic entry, layout, and simulation of digital integrated circuits using a disciplined standard-cell-based approach with Cadence Virtuoso.

VLSI III: Test and Fabrication of VLSI Circuits

Does not take place this semester.

Abstract

In this course, we will cover how modern microchips are fabricated, and we will focus on methods and tools to uncover fabrication defects, if any, in these microchips. As part of the exercises, students will get to work on an industrial 1 million dollar automated test equipment.

Objective

Learn about modern IC manufacturing methodologies, understand the problem of IC testing, Cover the basic methods, algorithms and techniques to test circuits in an efficient way. Learn about practical aspects of IC testing and apply what you learn in class using a state-of-the-art test equipment.

Content

This course will deal with modern integrated circuit (IC) manufacturing technology and cover topics such as:

- Today’s nanometer CMOS fabrication processes (HKMG).
- Optical and post optical Photolithography.
- Potential alternatives to CMOS technology and MOSFET devices.
- Evolution paths for design methodology.
- Industrial roadmaps for the future evolution of semiconductor technology (ITRS).

If you want to earn money by selling ICs, you will have to deliver a product that will function properly with a very large probability. The main emphasis of the lecture will be discussing how this can be achieved. We will discuss fault models and practical techniques to improve testability of VLSI circuits. At the IIS we have a state-of-the-art automated test equipment (Advantest SoC V93001) that we will make available for in class exercises and projects. At the end of the lecture you will be able to design state-of-the-art digital integrated circuits such as to make them testable and to use automatic test equipment (ATE) to carry out the actual testing.

During the first weeks of the course there will be weekly practical exercises where you will work in groups of two. For the last 5 weeks of the course students will be able to choose a class project that can be:

- The test of their own chip developed during a previous semester thesis
- Developing new setups and measurement methods in C++ on the tester
- Helping to debug problems encountered in previous microchips by IIS.

Lecture notes


Prerequisites / notice

Although this is the third part in a series of lectures on VLSI design, you can follow this course even if you have not visited VLSI I and VLSI II lectures. An interest in integrated circuit design, and basic digital circuit knowledge is required though.

Course website:
https://iis-students.ee.ethz.ch/lectures/vlsi-iii/

Information Theory I

W 6 credits 4G  A. Lapidoth

Abstract

This course covers the basic concepts of information theory and of communication theory. Topics covered include the entropy rate of a source, mutual information, typical sequences, the asymptotic equi-partition property, Huffman coding, channel capacity, the channel coding theorem, the source-channel separation theorem, and feedback capacity.

Objective

The fundamentals of Information Theory including Shannon's source coding and channel coding theorems

Content

- The entropy rate of a source, Typical sequences, the asymptotic equipartition property, the source-channel separation theorem, Huffman coding, Arithmetic coding, channel capacity, the channel coding theorem, the source-channel separation theorem, feedback capacity

Literature

T.M. Cover and J. Thomas, Elements of Information Theory (second edition)

Signal Analysis, Models, and Machine Learning

W 6 credits 4G  H.-A. Loeliger

Abstract

Mathematical methods in signal processing and machine learning.

I. Linear signal representation and approximation: Hilbert spaces, LMMSE estimation, regularization and sparsity.
II. Learning linear and nonlinear functions and filters: neural networks, kernel methods.
III. Structured statistical models: hidden Markov models, factor graphs, Kalman filter, Gaussian models with sparse events.

Objective

The course is an introduction to some basic topics in signal processing and machine learning.
### Prerequisites / notice

- local bachelors: course "Discrete-Time and Statistical Signal Processing" (5. Sem.)
- others: solid basics in linear algebra and probability theory

### 227-0124-00L Embedded Systems

**Abstract**
An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.

**Content**
Understanding specific requirements and problems arising in embedded system applications.

**Objective**
Understanding architectures and components, their hardware-software interfaces, the memory architecture, communication between components, embedded operating systems, real-time scheduling theory, shared resources, low-power and low-energy design as well as hardware architecture synthesis.

Using the formal models and methods in embedded system design and practical applications using the programming language C, the operating system FreeRTOS, a commercial embedded system platform and the associated design environment.

An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.

The focus of this lecture is on the design of embedded systems using formal models and methods as well as computer-based synthesis methods. Besides, the lecture is complemented by laboratory sessions where students learn how to program in C, to base their design on the embedded operating systems FreeRTOS, to use a commercial embedded system platform including sensors, and to edit/debug via an integrated development environment.

Specifically the following topics will be covered in the course: Embedded system architectures and components, hardware-software interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.

**Lecture notes**
The following information will be available: Lecture material, publications, exercise sheets and laboratory documentation at


**Literature**


### 227-0971-00L Computational Psychiatry

**Abstract**
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Content**
This six-day course teaches state-of-the-art methods in computational psychiatry. It covers various computational models of cognition (e.g., learning and decision-making) and brain physiology (e.g., effective connectivity) of relevance for psychiatric disorders. The course not only provides theoretical background, but also demonstrates open source software in application to concrete examples.

**Objective**
This course aims at bridging the gap between mathematical modelers and clinical neuroscientists by teaching computational techniques in the context of clinical applications. The hope is that the acquisition of a joint language and tool-kit will enable more effective communication and joint translational research between fields that are usually worlds apart.

### 252-0237-00L Concepts of Object-Oriented Programming

**Abstract**
Course that focuses on an in-depth understanding of object-oriented programming and compares designs of object-oriented programming languages. Topics include different flavors of type systems, inheritance models, encapsulation in the presence of aliasing, object and class initialization, program correctness, reflection

**Objective**
After this course, students will:
- Have a deep understanding of advanced concepts of object-oriented programming and their support through various language features.
- Be able to understand language concepts on a semantic level and be able to compare and evaluate language designs.
- Be able to learn new languages more rapidly.
- Be aware of many subtle problems of object-oriented programming and know how to avoid them.
Content
The main goal of this course is to convey a deep understanding of the key concepts of sequential object-oriented programming and their support in different programming languages. This is achieved by studying how important challenges are addressed through language features and programming idioms. In particular, the course discusses alternative language designs by contrasting solutions in languages such as C++, C#, Eiffel, Java, Python, and Scala. The course also introduces novel ideas from research languages that may influence the design of future mainstream languages.

The topics discussed in the course include among others:
- The pros and cons of different flavors of type systems (for instance, static vs. dynamic typing, nominal vs. structural, syntactic vs. behavioral typing)
- The key problems of single and multiple inheritance and how different languages address them
- Generic type systems, in particular, Java generics, C# generics, and C++ templates
- The situations in which object-oriented programming does not provide encapsulation, and how to avoid them
- The pitfalls of object initialization, exemplified by a research type system that prevents null pointer dereferencing
- How to maintain the consistency of data structures

Literature
Will be announced in the lecture.

Prerequisites
Mastering at least one object-oriented programming language (this course will NOT provide an introduction to object-oriented programming); programming experience

<table>
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<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites / Notice</th>
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</thead>
<tbody>
<tr>
<td>252-0417-00L</td>
<td>Randomized Algorithms and Probabilistic Methods</td>
<td>10</td>
<td>A. Steger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Las Vegas &amp; Monte Carlo algorithms: inequalities of Markov, Chebyshev, Chernoff; negative correlation; Markov chains: convergence, rapidly mixing; generating functions; Examples include: min cut, median, balls and bins, routing in hypercubes, SSAT, card shuffling, random walks</td>
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<tr>
<td>Objective</td>
<td>After this course students will know fundamental techniques from probabilistic combinatorics for designing randomized algorithms and will be able to apply them to solve typical problems in these areas.</td>
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</tr>
<tr>
<td>Content</td>
<td>Randomized Algorithms are algorithms that &quot;flip coins&quot; to take certain decisions. This concept extends the classical model of deterministic algorithms and has become very popular and useful within the last twenty years. In many cases, randomized algorithms are faster, simpler or just more elegant than deterministic ones. In the course, we will discuss basic principles and techniques and derive from them a number of randomized methods for problems in different areas.</td>
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<tr>
<td>Lecture notes</td>
<td>Yes.</td>
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<th>Credits</th>
<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>This course covers some of the fundamental concepts of computer graphics generation of photorealistic images from digital representations of 3D scenes and image-based methods for recovering digital scene representations from captured images.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>At the end of the course the students will be able to build a rendering system. The students will study the basic principles of rendering and image synthesis. In addition, the course is intended to stimulate the students' curiosity to explore the field of computer graphics in subsequent courses or on their own.</td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>This course covers fundamental concepts of modern computer graphics. Students will learn about 3D object representations and the details of how to generate photorealistic images from digital representations of 3D scenes. Starting with an introduction to 3D shape modeling, geometry representation and texture mapping, we will move on to the physics of light transport, acceleration structures, appearance modeling and Monte Carlo integration. We will apply these principles for computing light transport of direct and global illumination due to surfaces and participating media. We will end with an overview of modern image-based capture and image synthesis methods, covering topics such as geometry and material capture, light-fields and depth-image based rendering.</td>
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<tr>
<td>Lecture notes</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature</td>
<td>Books:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting</td>
<td></td>
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<tr>
<td></td>
<td>Multiple view geometry in computer vision</td>
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<tr>
<td></td>
<td>Physically Based Rendering: From Theory to Implementation</td>
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<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0546-00L</td>
<td>Physically-Based Simulation in Computer Graphics</td>
<td>5</td>
<td>V. da Costa de Azevedo, B. Solenthaler, B. Thomaszewski</td>
</tr>
<tr>
<td>Abstract</td>
<td>This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>This lecture provides an introduction to physically-based animation in computer graphics and gives an overview of fundamental methods and algorithms. The practical exercises include three assignments which are to be solved in small groups. In an additional course project, topics from the lecture will be implemented into a 3D game or a comparable application.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>The lecture covers topics in physically-based modeling, such as particle systems, mass-spring models, finite difference and finite element methods. These approaches are used to represent and simulate deformable objects or fluids with applications in animated movies, 3D games and medical systems. Furthermore, the lecture covers topics such as rigid body dynamics, collision detection, and character animation.</td>
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<tr>
<td>Prerequisites / Notice</td>
<td>Fundamentals of calculus and physics, basic concepts of algorithms and data structures, basic programming skills in C++, Knowledge on numerical mathematics as well as ordinary and partial differential equations is an asset, but not required.</td>
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</tbody>
</table>

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<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>261-5100-00L</td>
<td>Computational Biomedicine</td>
<td>5</td>
<td>V. Boeva, G. Rätsch</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course critically reviews central problems in Biomedicine and discusses the technical foundations and solutions for these problems.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Over the past years, rapid technological advancements have transformed classical disciplines such as biology and medicine into fields of applied data science. While the sheer amount of the collected data often makes computational approaches inevitable for analysis, it is the domain specific structure and close relation to research and clinic, that call for accurate, robust and efficient algorithms. In this course we will critically review central problems in Biomedicine and will discuss the technical foundations and solutions for these problems.</td>
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</tbody>
</table>

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Content

The course will consist of three topic clusters that will cover different aspects of data science problems in Biomedicine:

1) String algorithms for the efficient representation, search, comparison, composition and compression of large sets of strings, mostly originating from DNA or RNA Sequencing. This includes genome assembly, efficient index data structures for strings and graphs, alignment techniques as well as quantitative approaches.

2) Statistical models and algorithms for the assessment and functional analysis of individual genomic variations. This includes the identification of variants, prediction of functional effects, imputation and integration problems as well as the association with clinical phenotypes.

3) Models for organization and representation of large scale biomedical data. This includes ontology concepts, biomedical databases, sequence annotation and data compression.

Prerequisites / notice


<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Semester</th>
<th>Credits</th>
<th>Lectures</th>
<th>Period</th>
<th>Lecturer</th>
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<tbody>
<tr>
<td>401-3621-00L</td>
<td>Fundamentals of Mathematical Statistics</td>
<td>W</td>
<td>10</td>
<td>4V+1U</td>
<td>S. van de Geer</td>
<td></td>
</tr>
<tr>
<td>401-3627-00L</td>
<td>High-Dimensional Statistics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. L. Bühlmann</td>
<td></td>
</tr>
<tr>
<td>401-4623-00L</td>
<td>Time Series Analysis</td>
<td>W</td>
<td>6</td>
<td>3G</td>
<td>F. Balabdaoui</td>
<td></td>
</tr>
<tr>
<td>401-3901-00L</td>
<td>Linear &amp; Combinatorial Optimization</td>
<td>W</td>
<td>11</td>
<td>4V+2U</td>
<td>R. Zenklusen</td>
<td></td>
</tr>
</tbody>
</table>

Abstract

401-3621-00L Fundamentals of Mathematical Statistics
The course covers the basics of inferential statistics.

401-3627-00L High-Dimensional Statistics
"High-Dimensional Statistics" deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

401-4623-00L Time Series Analysis
The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

401-3901-00L Linear & Combinatorial Optimization
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective

401-3621-00L Knowledge of methods and basic theory for high-dimensional statistical inference
401-3627-00L Knowledge of methods and basic theory for high-dimensional statistical inference
401-4623-00L The goal of the course is to have a a good overview of the different types of time series and the approaches used in their statistical analysis.
401-3901-00L The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content

401-3621-00L The key topics which will be covered as:
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

401-3627-00L
- Lasso and Group Lasso for high-dimensional linear and generalized linear models;
- Additive models and many smooth univariate functions;
- Non-convex loss functions and l1-regularization;
- Stability selection, multiple testing and construction of p-values;
- Undirected graphical modeling

401-4623-00L
- Stationarity
- Autocorrelation
- Trend estimation
- Elimination of seasonality
- Spectral analysis, spectral densities
- Forecasting
- ARMA, ARIMA, Introduction into GARCH models

401-3901-00L
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

401-3621-00L The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis


401-4623-00L The main reference for this course is the book "Introduction to Time Series and Forecasting", by P. J. Brockwell and R. A. Davis


Prerequisites / notice

401-3621-00L Basic knowledge in probability and statistics
401-3627-00L Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).
401-4623-00L Basic knowledge in probability and statistics
401-3901-00L Solid background in linear algebra.

Former course title: Mathematical Optimization.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

MATHEMATICS OF DATA SCIENCE

Masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective
Introduction to various mathematical aspects of Data Science.

Content
These topics lie in overlaps of (Applied) Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Each lecture will feature a couple of Mathematical Open Problem(s) related to Data Science. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

Lecture notes

Prerequisites / notice
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and “227-0434-10L Mathematics of Information” taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

NEURAL NETWORK THEORY

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

Objective
After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.

Content
1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

Lecture notes
Detailed lecture notes are available on the course web page
https://www.mins.ee.ethz.ch/teaching/nnt/

Prerequisites / notice
This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

NEUROMORPHIC ENGINEERING I

Registration in this class requires the permission of the instructors. Class size will be limited to available lab spots. Preference is given to students that require this class as part of their major.

Information for UZH students:
Enrolment to this course unit only possible at ETH. No enrolment to module INI404 at UZH.
Please mind the ETH enrolment deadlines for UZH students: https://www.ethz.ch/en/studies/non-degree-courses/special-students-university-of-zurich.html
Abstract
This course covers analog circuits with emphasis on neuromorphic engineering: MOS transistors in CMOS technology, static circuits, dynamic circuits, systems (silicon neuron, silicon retina, silicon cochlea) with an introduction to multi-chip systems. The lectures are accompanied by weekly laboratory sessions.

Objective
Understanding of the characteristics of neuromorphic circuit elements.

Content
Neuromorphic circuits are inspired by the organizing principles of biological neural circuits. Their computational primitives are based on physics of semiconductor devices. Neuromorphic architectures often rely on collective computation in parallel networks. Adaptation, learning and memory are implemented locally within the individual computational elements. Transistors are often operated in weak inversion (below threshold), where they exhibit exponential I-V characteristics and low currents. These properties lead to the feasibility of high-density, low-power implementations of functions that are computationally intensive in other paradigms. Application domains of neuromorphic circuits include silicon retinas and cochleas for machine vision and audition, real-time emulations of networks of biological neurons, and the development of autonomous robotic systems. This course covers devices in CMOS technology (MOS transistor below and above threshold, floating-gate MOS transistor, phototransducers), static circuits (differential pair, current mirror, transconductance amplifiers, etc.), dynamic circuits (linear and nonlinear filters, adaptive circuits), systems (silicon neuron, silicon retina and cochlea) and an introduction to multi-chip systems that communicate events analogous to spikes. The lectures are accompanied by weekly laboratory sessions on the characterization of neuromorphic circuits, from elementary devices to systems.

Literature
S.-C. Liu et al.; Analog VLSI Circuits and Principles; various publications.

Prerequisites / notice
Particular: The course is highly recommended for those who intend to take the spring semester course ‘Neuromorphic Engineering II’, that teaches the conception, simulation, and physical layout of such circuits with chip design tools.

Prerequisites: Background in basics of semiconductor physics helpful, but not required.

<table>
<thead>
<tr>
<th>327-1201-00L</th>
<th>Transport Phenomena I</th>
<th>W</th>
<th>5 credits</th>
<th>4G</th>
<th>J. Vermant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Phenomenological approach to “Transport Phenomena” based on balance equations supplemented by thermodynamic considerations to formulate the undetermined fluxes in the local species mass, momentum, and energy balance equations; Solutions of a few selected problems relevant to materials science and engineering both analytical and using numerical methods.</td>
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<tr>
<td>Objective</td>
<td>The teaching goals of this course are on five different levels: (1) Deep understanding of fundamentals: local balance equations, constitutive equations for fluxes, entropy balance, interfaces, idea of dimensionless numbers and scaling, (2) Ability to use the fundamental concepts in applications, (3) Insight into the role of boundary conditions (mainly part 2), (4) Knowledge of a number of applications, (5) Flavor of numerical techniques: finite elements and finite differences.</td>
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<tr>
<td>Content</td>
<td>Part 1 Approach to Transport Phenomena (Equilibrium Thermodynamics), Balance Equations, Forces and Fluxes, Applications (1. Measuring Transport Coefficients, 2. Fluid mechanics, 3. combined heat and flow)</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Complex numbers, Vector analysis (integrability; Gauss’ divergence theorem), Laplace and Fourier transforms. Ordinary differential equations (basic ideas). Linear algebra (matrices; functions of matrices; eigenvectors and eigenvalues; eigentfuctions). Probability theory (Gaussian distributions; Poisson distributions; averages; moments; variances; random variables). Numerical mathematics (integration), Equilibrium thermodynamics (Gibbs’ fundamental equation; thermodynamic potentials; Legendre transforms). Maxwell equations. Programming and simulation techniques (Matlab, Monte Carlo simulations).</td>
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<tr>
<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies: Concepts and Theories, Techniques and Technologies, Domain B - Method-specific Competencies: Problem-solving</td>
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<tr>
<td>252-3005-00L</td>
<td>Natural Language Processing</td>
<td>W</td>
<td>5 credits</td>
<td>2V+2U+1A</td>
<td>R. Cotterell</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.</td>
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<tr>
<td>Objective</td>
<td>The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.</td>
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<tr>
<td>Content</td>
<td>This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.</td>
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<tr>
<td>Literature</td>
<td>Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.</td>
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<tr>
<td>263-2400-00L</td>
<td>Reliable and Trustworthy Artificial Intelligence</td>
<td>W</td>
<td>6 credits</td>
<td>2V+2U+1A</td>
<td>M. Vechev</td>
</tr>
<tr>
<td>Abstract</td>
<td>Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting advances that bring us closer to constructing such models.</td>
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<tr>
<td>Objective</td>
<td>The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.</td>
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<tr>
<td>To facilitate deeper understanding, an important part of the course will be a group hands-on programming project where students will build a system based on the learned material.</td>
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</tbody>
</table>
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

* Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
* Defenses against attacks
* Combining gradient-based optimization with logic for encoding background knowledge
* Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
* Probabilistic certification of deep neural networks
* Training deep neural networks to be provably robust via automated reasoning
* Fairness (different notions of fairness, certifiably fair representation learning)
* Federated Learning (introduction, security considerations)

While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in “Intro to ML” classes at most institutions (e.g., “Introduction to Machine Learning” at ETH).

For solving assignments, some programming experience in Python is expected.

see also Fields of Specialization

### Case Studies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3667-71L</td>
<td>Case Studies Seminar (Autumn Semester 2021)</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>V. C. Gradinaru, R. Hiptmair, M. Reiher</td>
</tr>
</tbody>
</table>

**Abstract**

Invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list. Students have to register their presentations online on https://rw.ethz.ch/the-programme/case-studies.html by the first week of the teaching period.

**Content**

In the CSE Case Studies Seminar invited speakers from ETH, from other universities as well as from industry give a talk on an applied topic. Beside of attending the scientific talks students are asked to give short presentations (10 minutes) on a published paper out of a list (containing articles from, e.g., Nature, Science, Scientific American, etc.). If the underlying paper comprises more than 15 pages, two or three consecutive case studies presentations delivered by different students can be based on it. Consistency in layout, style, and contents of those presentations is expected.

Students have to register their presentations online on https://rw.ethz.ch/the-programme/case-studies.html by the first week of the teaching period.

**Prerequisites / notice**

The talks might be given via Zoom; talks in presence should be also streamed in Zoom.

75% attendance and a short presentation on a published paper out of a list or on some own project are mandatory.

Students have to register their presentations online until the second Wednesday of the semester on https://rw.ethz.ch/the-programme/case-studies.html

The student talks will be grouped by subject, so we'll decide the actual dates of the individual talks.

Students that realize that they will not fulfill this criteria have to contact the teaching staff or de-register before the end of semester from the Seminar if they want to avoid a “Fail” in their documents. Later de-registrations will not be considered.

**Taught competencies**

- **Domain A - Subject-specific Competencies**
  - Techniques and Technologies
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management
  - Communication
  - Cooperation and Teamwork
  - Creativity and Flexibility
  - Critical Thinking
  - Integrity and Work Ethics
  - Self-awareness and Self-reflection
  - Self-direction and Self-management

- **Domain B - Method-specific Competencies**
  - Analytical Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- **Domain C - Social Competencies**
  - Communication

- **Domain D - Personal Competencies**
  - Adaptability and Flexibility
  - Critical Thinking

**Semester Paper**

There are several course units “Semester Paper” that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3740-01L</td>
<td>Semester Paper</td>
<td>W</td>
<td>8 credits</td>
<td>11A</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

Successful participation in the course unit 401-2000-00L, Scientific Works in Mathematics or 402-2000-00L, Scientific Works in Physics is required.

For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html

Supervisors only authorised for term papers must be assigned by the Study Administration.

**Objective**

Semester papers help to deepen the students’ knowledge of a specific subject area. Students are offered a selection of topics. These papers serve to develop the students’ ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.
There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

401-3740-02L  
Semester Paper (No. 2)  
Successful participation in the course unit 401-2000-00L  
Scientific Works in Mathematics or 402-2000-00L  
Scientific Works in Physics is required. 
For more information, see www.math.ethz.ch/intranet/students/study-administration/theses.html  
Supervisors only authorised for term papers must be assigned by the Study Administration.

Abstract  
Semester Papers help to deepen the students' knowledge of a specific subject area. Students are offered a selection of topics. These papers serve to develop the students' ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.

Objective  
Semester papers serve to develop the students' ability for independent mathematical work as well as to enhance skills in presenting mathematical results in writing.

Prerequisites / notice  
There are several course units "Semester Paper" that are all equivalent. If, during your studies, you write several semester papers, choose among the different numbers in order to be able to obtain credits again.

W  8 credits  11A  Supervisors

GESS Science in Perspective

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree.

see https://ethz.ch/content/dam/ethz/common/docs/weisungssammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.)

see Science in Perspective: Language Courses ETH/UZH

Recommended Science in Perspective (Type B) for D-MATH.

Master's Thesis

If you wish to have recognised 402-2000-00L Scientific Works in Physics instead of 401-2000-00L Scientific Works in Mathematics (as allowed for the CSE programme), take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat) after having passed the performance assessment.

Number  Title  Type  ECTS  Hours  Lecturers

401-2000-00L  Scientific Works in Mathematics  O  0 credits  M. Burger

Target audience:  
Third year Bachelor students;  
Master students who cannot document to have received an adequate training in working scientifically.

Abstract  
Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others.)

Objective  
Learn the basic standards of scientific works in mathematics.

Content  
- Types of mathematical works  
- Publication standards in pure and applied mathematics  
- Data handling  
- Ethical issues  
- Citation guidelines

Prerequisites / notice  

401-2000-01L  Lunch Sessions – Thesis Basics for Mathematics  Z  0 credits  Speakers

Students  
Details and registration for the optional MathBib training course: https://www.math.ethz.ch/mathbib-schulungen

Abstract  
Optional MathBib training course

402-2000-00L  Scientific Works in Physics  W  0 credits  C. Eichler

Target audience:  
Master students who cannot document to have received an adequate training in working scientifically.


Abstract  
Literature Review: ETH-Library, Journals in Physics, Google Scholar; Thesis Structure: The IMRAD Model; Document Processing: LaTeX and BibTeX, Mathematical Writing, AVETH Survival Guide; ETH Guidelines for Integrity; Authorship Guidelines; ETH Citation Etiquettes; Declaration of Originality.

Objective  
Basic standards for scientific works in physics: How to write a Master Thesis. What to know about research integrity.

401-4990-01L  Master's Thesis  O  30 credits  57D  Supervisors

Only students who fulfill the following criteria are permitted to commence the Master's thesis:  
a. successful completion of the Bachelor's programme;  
b. fulfilling of any additional requirements necessary to gain admission to the Master's programme;  
c. successful completion of  
1) at least two course units in the category 'Core courses';  
2) at least five course units, including a seminar, in the category 'Fields of specialisation'; and
3) the semester paper.
Successful participation in the course unit 401-2000-00L
Scientific Works in Mathematics or 402-2000-00L
Scientific Works in Physics is required.
For more information, see
www.math.ethz.ch/intranet/students/study-administration/theses.html

Abstract
The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.

Objective
Thesis work should prove the students' ability to independent, structured and scientific working.

▶ Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-5650-00L</td>
<td>Zurich Colloquium in Applied and Computational Mathematics</td>
<td>E-</td>
<td>0 credits</td>
<td>1K</td>
<td>R. Abgrall, R. Alaifari, H. Ammari, R. Hiptmair, S. Mishra, S. Sauter</td>
</tr>
<tr>
<td>Abstract</td>
<td>Research colloquium</td>
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</table>

▶ Course Units for Additional Admission Requirements
The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0353-AAL</td>
<td>Analysis III</td>
<td>E-</td>
<td>4 credits</td>
<td>9R</td>
<td>A. Iozzi</td>
</tr>
</tbody>
</table>

Abstract
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Objective
Mathematical treatment of problems in science and engineering. To understand the properties of the different types of partial differential equations.

Content
- Laplace Transforms:
  - Laplace Transform, Inverse Laplace Transform, Linearity, s-Shifting
  - Transforms of Derivatives and Integrals, ODEs
  - Unit Step Function, t-Shifting
  - Short Impulses, Dirac's Delta Function, Partial Fractions
  - Convolution, Integral Equations
  - Differentiation and Integration of Transforms

- Fourier Series, Integrals and Transforms:
  - Fourier Series
  - Functions of Any Period p=2L
  - Even and Odd Functions, Half-Range Expansions
  - Forced Oscillations
  - Approximation by Trigonometric Polynomials
  - Fourier Integral
  - Fourier Cosine and Sine Transform

- Partial Differential Equations:
  - Basic Concepts
  - Modeling: Vibrating String, Wave Equation
  - Solution by separation of variables; use of Fourier series
  - D'Alambert Solution of Wave Equation, Characteristics
  - Heat Equation: Solution by Fourier Series
  - Heat Equation: Solutions by Fourier Integrals and Transforms
  - Modeling Membrane: Two Dimensional Wave Equation
  - Laplacian in Polar Coordinates: Circular Membrane, Fourier-Bessel Series
  - Solution of PDEs by Laplace Transform

Literature

For reference/complement of the Analysis I/II courses:
Christian Blatter: Ingenieur-Analysis (Download PDF)
Up-to-date information about this course can be found at:
http://www.math.ethz.ch/education/bachelor/lectures/hs2013/other/analysis3_itet

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0603-AAL</td>
<td>Stochastics (Probability and Statistics)</td>
<td>E-</td>
<td>4 credits</td>
<td>9R</td>
<td>M. Kalisch</td>
</tr>
</tbody>
</table>

Abstract
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.
Objective

The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content

From "Statistics for research" (online)
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

Literature

- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under:

  From within the ETH, this book is freely available online under:
  http://www.springerlink.com/content/m17578/

401-2673-AAL Numerical Methods for CSE

10 credits

Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

The course gives an introduction into fundamental techniques and algorithms of numerical mathematics which play a central role in numerical simulations in science and technology. The course focuses on fundamental ideas and algorithmic aspects of numerical methods.

The exercises involve actual implementation of numerical methods in C++.

Objective

* Knowledge of the fundamental algorithms in numerical mathematics
* Knowledge of the essential terms in numerical mathematics and the techniques used for the analysis of numerical algorithms
* Ability to choose the appropriate numerical method for concrete problems
* Ability to interpret numerical results
* Ability to implement numerical algorithms efficiently

Content

* Direct Methods for linear systems of equations
* Least Squares Techniques
* Data Interpolation and Fitting
* Filtering Algorithms
* Approximation of Functions
* Numerical Quadrature
* Iterative Methods for non-linear systems of equations

Lecture notes

Lecture materials (PDF documents and codes) will be made available to participants.

Literature


M. Hanke-Bourgeois "Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens", BG Teubner, 2002

P. Deuflhard and A. Hohmann, "Numerische Mathematik I", DeGruyter, 2002

Prerequisites / notice

Solid knowledge about fundamental concepts and techniques from linear algebra & calculus as taught in the first year of science and engineering curricula.

The course will be accompanied by programming exercises in C++ relying on the template library EIGEN. Familiarity with C++, object oriented and generic programming is an advantage. Participants of the course are expected to learn C++ by themselves.

401-0674-AAL Numerical Methods for Partial Differential Equations

10 credits

Enrolment ONLY for MSc students with a degree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Derivation, properties, and implementation of fundamental numerical methods for a few key partial differential equations: convection-diffusion, heat equation, wave equation, conservation laws. Implementation in C++ based on a finite element library.

Objective

Main skills to be acquired in this course:

* Ability to implement fundamental numerical methods for the solution of partial differential equations efficiently.
* Ability to modify and adapt numerical algorithms guided by awareness of their mathematical foundations.
* Ability to select and assess numerical methods in light of the predictions of theory
* Ability to identify features of a PDE (= partial differential equation) based model that are relevant for the selection and performance of a numerical algorithm.
* Ability to understand research publications on theoretical and practical aspects of numerical methods for partial differential equations.
* Skills in the efficient implementation of finite element methods on unstructured meshes.

This course is neither a course on the mathematical foundations and numerical analysis of methods nor an course that merely teaches recipes and how to apply software packages.
1 Case Study: A Two-point Boundary Value Problem [optional]

1.1 Introduction

1.2 A model problem

1.3 Variational approach

1.4 Simplified model

1.5 Discretization

1.5.1 Galerkin discretization

1.5.2 Collocation [optional]

1.5.3 Finite differences

1.6 Convergence

2 Second-order Scalar Elliptic Boundary Value Problems

2.1 Equilibrium models

2.1.1 Taut membrane

2.1.2 Electrostatic fields

2.1.3 Quadratic minimization problems

2.2 Sobolev spaces

2.3 Variational formulations

2.4 Equilibrium models: Boundary value problems

3 Finite Element Methods (FEM)

3.1 Galerkin discretization

3.2 Case study: Triangular linear FEM in two dimensions

3.3 Building blocks of general FEM

3.4 Lagrangian FEM

3.4.1 Simplicial Lagrangian FEM

3.4.2 Tensor-product Lagrangian FEM

3.5 Implementation of FEM in C++

3.5.1 Mesh file format (Gmsh)

3.5.2 Mesh data structures (DUNE)

3.5.3 Assembly

3.5.4 Local computations and quadrature

3.5.5 Incorporation of essential boundary conditions

3.6 Parametric finite elements

3.6.1 Affine equivalence

3.6.2 Example: Quadrilateral Lagrangian finite elements

3.6.3 Transformation techniques

3.6.4 Boundary approximation

3.7 Linearization [optional]

4 Finite Differences (FD) and Finite Volume Methods (FV) [optional]

4.1 Finite differences

4.2 Finite volume methods (FVM)

5 Convergence and Accuracy

5.1 Galerkin error estimates

5.2 Empirical Convergence of FEM

5.3 Finite element error estimates

5.4 Elliptic regularity theory

5.5 Variational crimes

5.6 Duality techniques [optional]

5.7 Discrete maximum principle [optional]

6 2nd-Order Linear Evolution Problems

6.1 Parabolic initial-boundary value problems

6.1.1 Heat equation

6.1.2 Spatial variational formulation

6.1.3 Method of lines

6.1.4 Timestepping

6.1.5 Convergence

6.2 Wave equations [optional]

6.2.1 Vibrating membrane

6.2.2 Wave propagation

6.2.3 Method of lines

6.2.4 Timestepping

6.2.5 CFL-condition

7 Convection-Diffusion Problems [optional]

7.1 Heat conduction in a fluid

7.1.1 Modelling fluid flow

7.1.2 Heat convection and diffusion

7.1.3 Incompressible fluids

7.1.4 Transient heat conduction

7.2 Stationary convection-diffusion problems

7.2.1 Singular perturbation

7.2.2 Upwinding

7.3 Transient convection-diffusion BVP

7.3.1 Method of lines

7.3.2 Transport equation

7.3.3 Lagrangian split-step method

7.3.4 Semi-Lagrangian method

8 Numerical Methods for Conservation Laws

8.1 Conservation laws: Examples

8.2 Scalar conservation laws in 1D

8.3 Conservative finite volume discretization

8.3.1 Semi-discrete conservation form

8.3.2 Discrete conservation property

8.3.3 Numerical flux functions

8.3.4 Monotone schemes

8.4 Timestepping

8.4.1 Linear stability

8.4.2 CFL-condition

8.4.3 Convergence

8.5 Higher order conservative schemes [optional]

8.5.1 Slope limiting
8.5.2 MUSCL scheme
8.6. FV-schemes for systems of conservation laws [optional]

“optional” indicates that the corresponding topic might be skipped depending on the progress of the course.

Lecture notes
- The lecture will be taught in flipped classroom format.
- Video tutorials for all thematic units will be published online.
- Solution of homework problems will partly be covered by video tutorials.
- Lecture documents and tablet notes accompanying the videos will be made available to the audience as PDF.

Literature
- Chapters of the following books provide supplementary reading (detailed references in course material):

However, study of supplementary literature is not important for for following the course.

Prerequisites / notice
- Mastery of basic calculus and linear algebra is taken for granted.
- Familiarity with fundamental numerical methods (solution methods for linear systems of equations, interpolation, approximation, numerical quadrature, numerical integration of ODEs) is essential.

Important: Coding skills and experience in C++ are essential.

Homework assignments involve substantial coding, partly based on a C++ finite element library. The written examination will be computer based and will comprise coding tasks.

The course will be taught in flipped classroom format:
- Video tutorials for all thematic units will be published online.
- Solution of homework problems will partly be covered by video tutorials.
- Lecture documents and tablet notes accompanying the videos will be made available to the audience as PDF.

Lectures
- Chapters of the following books provide supplementary reading (detailed references in course material):

However, study of supplementary literature is not important for following the course.

Prerequisites / notice
- Mastery of basic calculus and linear algebra is taken for granted.
- Familiarity with fundamental numerical methods (solution methods for linear systems of equations, interpolation, approximation, numerical quadrature, numerical integration of ODEs) is essential.

Important: Coding skills and experience in C++ are essential.

Homework assignments involve substantial coding, partly based on a C++ finite element library. The written examination will be computer based and will comprise coding tasks.

252-0232-AAL Software Engineering

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This course introduces both theoretical and applied aspects of software engineering. It covers:

- Software Architecture
- Informal and formal Modeling
- Design Patterns
- Software Engineering Principles
- Code Refactoring
- Program Testing

Objective
The course has two main objectives:

- Obtain an end-to-end (both, theoretical and practical) understanding of the core techniques used for building quality software.
- Be able to apply these techniques in practice.

Content
The course is an introduction to the theoretical foundations of software engineering. The students will apply these techniques in project work that will span the whole semester - involving all aspects of software engineering, from understanding requirements over design and implementation to deployment and change requests.

Literature
Will be announced in the lecture
### Core Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>151-0107-20L</td>
<td>High Performance Computing for Science and Engineering (HPCSE) I</td>
<td>W</td>
<td>4</td>
<td>4G</td>
<td>P. Koumoutsakos, S. M. Martin</td>
</tr>
</tbody>
</table>

**Abstract**
This course gives an introduction into algorithms and numerical methods for parallel computing on shared and distributed memory architectures. The algorithms and methods are supported with problems that appear frequently in science and engineering.

**Objective**
With manufacturing processes reaching its limits in terms of transistor density on today’s computing architectures, efficient utilization of computing resources must include parallel execution to maintain scaling. The use of computers in academia, industry and society is a fundamental tool for problem solving today while the “think parallel” mind-set of developers is still lagging behind.

The aim of the course is to introduce the student to the fundamentals of parallel programming using shared and distributed memory programming models. The goal is on learning to apply these techniques with the help of examples frequently found in science and engineering and to deploy them on large scale high performance computing (HPC) architectures.

1. Hardware and Architecture: Moore’s Law, Instruction set architectures (MIPS, RISC, CISC), Instruction pipelines, Caches, Flynn’s taxonomy, Vector instructions (for Intel x86)

2. Shared memory parallelism: Threads, Memory models, Cache coherency, Mutual exclusion, Uniform and Non-Uniform memory access, Open Multi-Processing (OpenMP)

3. Distributed memory parallelism: Message Passing Interface (MPI), Point-to-Point and collective communication, Blocking and non-blocking methods, Parallel file I/O, Hybrid programming models

4. Performance and parallel efficiency analysis: Performance analysis of algorithms, Roofline model, Amdahl’s Law, Strong and weak scaling analysis

5. Applications: HPC Math libraries, Linear Algebra and matrix/vector operations, Singular value decomposition, Neural Networks and linear autoencoders, Solving partial differential equations (PDEs) using grid-based and particle methods

**Lecture notes**
https://www.cse-lab.ethz.ch/teaching/hpcse-i_hs21/
Class notes, handouts

**Literature**
- An Introduction to Parallel Programming, P. Pacheco, Morgan Kaufmann
- Introduction to High Performance Computing for Scientists and Engineers, G. Hager and G. Wellein, CRC Press
- Computer Organization and Design, D.H. Patterson and J.L. Hennessy, Morgan Kaufmann
- Vortex Methods, G.H. Cottet and P. Koumoutsakos, Cambridge University Press
- Lecture notes

**Prerequisites / notice**
Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++.
The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

| 151-0325-00L | Planning and Decision Making for Autonomous Robots | W    | 4    | 2+1U  | E. Frazzoli                      |

**Abstract**
Planning safe and efficient motions for robots in complex environments, often shared with humans and other robots, is a difficult problem combining discrete and continuous mathematics, as well as probabilistic, game-theoretic, and learning aspects. This course will cover the algorithmic foundations of motion planning, with an eye to real-world implementation issues.

**Objective**
The students will learn how to design and implement state-of-the-art algorithms for planning the motion of robots executing challenging tasks in complex environments.

**Content**

**Lecture notes**
Course notes and other education material will be provided for free in an electronic form.

**Literature**
There is no required textbook, but an excellent reference is Steve Lalonde's book on "Planning Algorithms."
Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with basic programming (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Techniques and Technologies

**Prerequisites / notice**
Students should have taken basic courses in optimization, control systems, probability theory, and should be familiar with basic programming (e.g., Python, and/or C/C++). Previous exposure to robotic systems is a definite advantage.

| 151-0371-00L | Advanced Model Predictive Control | W    | 4    | 2+1U  | M. Zeilinger, A. Carron, L. Hewing, J. Köhler |

**Abstract**
Model predictive control (MPC) has established itself as a powerful control technique for complex systems under state and input constraints. This course discusses the theory and application of recent advanced MPC concepts, focusing on system uncertainties and safety, as well as data-driven formulations and learning-based control.

**Objective**
Design, implement and analyze advanced MPC formulations for robust and stochastic uncertainty descriptions, in particular with data-driven formulations.

**Content**
Topics include:
- Review of Bayesian statistics, stochastic systems and Stochastic Optimal Control
- Nominal MPC for uncertain systems (nominal robustness)
- Robust MPC
- Stochastic MPC
- Set-membership Identification and robust data-driven MPC
- Bayesian regression and stochastic data-driven MPC
- MPC as safety filter for reinforcement learning

**Lecture notes**
Lecture notes will be provided.

**Prerequisites / notice**
Basic courses in control, advanced course in optimal control, basic MPC course (e.g. 151-0660-00L Model Predictive Control) strongly recommended. Background in linear algebra and stochastic systems recommended.

| 151-0509-00L | Microscale Acoustofluidics | W    | 4    | 3G    | J. Dual                          |

**Abstract**
In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and nonlinear mechanics perspective with applications to microsystems and lab on a chip devices.

**Objective**
Understanding acoustophoresis, the design of devices and potential applications

**Content**
Linear and nonlinear acoustics, foundations of fluid and solid mechanics and piezoelectricity, Gorkov potential, numerical modelling, acoustic streaming, applications from ultrasonic microbubbles to surface acoustic wave devices
This course provides a comprehensive overview of embedded control systems. The concepts introduced are implemented and verified on a microprocessor-controlled haptic device.

An embedded system is a microprocessor used as a component in another piece of technology, such as cell phones or automobiles. In this intensive two-week block course the students are presented the principles of embedded digital control systems using a haptic device as an example for a mechatronic system. A haptic interface allows for a human to interact with a computer through the sense of touch.

Subjects covered in lectures and practical lab exercises include:
- The application of C-programming on a microprocessor
- Digital I/O and serial communication
- Quadrature decoding for wheel position sensing
- Queued analog-to-digital conversion to interface with the analog world
- Pulse width modulation
- Timer interrupts to create sampling time intervals
- System dynamics and virtual worlds with haptic feedback
- Introduction to rapid prototyping

Lecture notes, lab instructions, supplemental material

This course is restricted to 33 students due to limited lab infrastructure. Interested students please contact Marianne Schmid Daners (E-Mail: marischm@ethz.ch) After your reservation has been confirmed please register online at www.mystudies.ethz.ch.

Detailed information can be found on the course website http://www.idsc.ethz.ch/education/lectures/embedded-control-systems.html

This course provides an introduction and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Robotics is often viewed from three perspectives: perception (sensing), manipulation (affecting changes in the world), and cognition (intelligence). Robotic systems integrate aspects of all three of these areas. This course provides an introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

An introduction to the theory of robotics, and covers the fundamentals of the field, including rigid motions, homogeneous transformations, forward and inverse kinematics of multiple degree of freedom manipulators, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control.

Available.

This course is an interdisciplinary field that combines aspects of robotics, micro and nanotechnology, biomedical engineering, and materials science. The aim of this course is to expose students to the fundamentals of this emerging field. Throughout the course, the students apply these concepts in assignments. The course concludes with an end-of-semester examination.

The objective of this course is to expose students to the fundamental aspects of the emerging field of microrobotics. This includes a focus on physical laws that predominate at the microscale, technologies for fabricating small devices, bio-inspired design, and applications of the field.
Main topics of the course include:
- Scaling laws at micro/nano scales
- Electrostatics
- Electromagnetism
- Low Reynolds number flows
- Observation tools
- Materials and fabrication methods
- Applications of biocmic microrobots

Lecture notes
The powerpoint slides presented in the lectures will be made available as pdf files. Several readings will also be made available electronically.

Prerequisites / notice
The lecture will be taught in English.

151-0632-00L Vision Algorithms for Mobile Robotics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: DINF2039

Lecture notes
Lecture slides will be made available on the course official website: http://rpg.ifi.uzh.ch/teaching.html

Abstract
For a robot to be autonomous, it has to perceive and understand the world around it. This course introduces you to the key computer vision algorithms used in mobile robotics, such as feature extraction, structure from motion, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry (the algorithms behind Hololens, Oculus Quest, and the NASA Mars rovers).

Objective
Learn the fundamental computer vision algorithms used in mobile robotics, in particular: filtering, feature extraction, structure from motion, multiple view geometry, dense reconstruction, tracking, image retrieval, event-based vision, and visual-inertial odometry and Simultaneous Localization And Mapping (SLAM) (the algorithms behind Hololens, Facebook-Oculus Quest, and the NASA Mars rovers).

Content
Each lecture will be followed by a lab session where you will learn to implement a building block of a visual odometry algorithm in Matlab.

Literature

Prerequisites / notice
Fundamentals of algebra, geometry, matrix calculus, and Matlab programming.

Note: If you are interested in taking UZH courses, you must register as an incoming mobility student at UZH. For details, see as follows:

UZH course enrollment for ETH student at University of Zurich (UZH) > Mobility within Switzerland – Incoming > Module Mobility: The easiest way to take individual modules/courses to supplement your studies at your home university is with module mobility. This option is not available to students who have dropped out of their home university or have been definitely excluded or banned from the relevant a program > Application and Deadlines: Applications are submitted via the UZH application portal (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html).

151-0851-00L Robot Dynamics

We will provide an overview on how to kinematically and dynamically model typical robotic systems such as robot arms, legged robots, rotary wing systems, or fixed wing.

Abstract
The primary objective of this course is that the student deepens an applied understanding of how to model the most common robotic systems. The student receives a solid background in kinematics, dynamics, and rotations of multi-body systems. On the basis of state of the art applications, he/she will learn all necessary tools to work in the field of design or control of robotic systems.

Objective
The course consists of three parts: First, we will refresh and deepen the student’s knowledge in kinematics, dynamics, and rotations of multi-body systems. In this context, the learning material will build upon the courses for mechanics and dynamics available at ETH, with the particular focus on their application to robotic systems. The goal is to foster the conceptual understanding of similarities and differences among the various types of robots. In the second part, we will apply the learned material to classical robotic arms as well as legged systems and discuss kinematic constraints and interaction forces. In the third part, focus is put on modeling fixed wing aircraft, along with related design and control concepts. In this context, we also touch aerodynamics and flight mechanics to an extent typically required in robotics. The last part finally covers different helicopter types, with a focus on quadrotors and the coaxial configuration which we see today in many UAV applications. Case studies on all main topics provide the link to real applications and to the state of the art in robotics.

Content
The lecture notes are available online via the UZH course portal (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html).

151-1116-00L Introduction to Aircraft and Car Aerodynamics

W 4 credits 3G M. Immer, F. Fröhder

Abstract
- Aircraft aerodynamics: Atmosphere; aerodynamic forces (lift, drag); thrust.

Objective
- An introduction to the basic principles and interrelationships of aircraft and automotive aerodynamics.
- To understand the basic relations of the origin of aerodynamic forces (ie lift, drag). To quantify the aerodynamic forces for basic configurations of aircraft and car components. Illustration of the intrinsic problems and results using examples.
- Using experimental and theoretical methods to illustrate possibilities and limits.

Content
- Aircraft aerodynamics: atmosphere, aerodynamic forces (ascending force; profile, wings, Resistance, residual resistance, induced resistance); thrust (overview of the propulsion system, aerodynamics of the propellers), introduction to static longitudinal stability.

Prepareations and slides are provided prior to each class.

Note: The previous course title in German until HS20 “Einführung in Flug- und Fahrzeugaerodynamik”.
Literature

Aircraft Aerodynamics:
- Schlichting,H und Truckenbrodt, E: Aerodynamik des Flugzeuge (Bd I und II), Springer Verlag, 1960
- Hoerner, S.F.: Fluid Dynamic Lift, Hoerner Fluid Dynamics, 1975

Vehicle Aerodynamics

151-0532-00L Nonlinear Dynamics and Chaos I
W 4 credits 2V+2U G. Haller

Abstract
Basic facts about nonlinear systems; stability and near-equilibrium dynamics; bifurcations; dynamical systems on the plane; non-
autonomous dynamical systems; chaotic dynamics.

Objective
This course is intended for Masters and Ph.D. students in engineering sciences, physics and applied mathematics who are interested in the
behavior of nonlinear dynamical systems. It offers an introduction to the qualitative study of nonlinear physical phenomena modeled by
differential equations. We discuss applications in classical mechanics, electrical engineering, fluid mechanics, and
biology. A more advanced Part II of this class is offered every other year.

Content
(1) Basic facts about nonlinear systems: Existence, uniqueness, and dependence on initial data.
(2) Near equilibrium dynamics: Linear and Lyapunov stability
(3) Bifurcations of equilibria: Center manifolds, normal forms, and elementary bifurcations
(4) Nonlinear dynamical systems on the plane: Phase plane techniques, limit sets, and limit cycles.
(5) Time-dependent dynamical systems: Floquet theory, Poincare maps, averaging methods, resonance

Lecture notes
The class lecture notes will be posted electronically after each lecture. Students should not rely on these but prepare their own notes
during the lecture.

Prerequisites / notice
- Prerequisites: Analysis, linear algebra and a basic course in differential equations.
- Exam: two-hour written exam in English.
- Homework: A homework assignment will be due roughly every other week. Hints to solutions will be posted after the homework due
dates.

227-0102-00L Discrete Event Systems
W 6 credits 4G R. Jacob, L. Vanbever, R. Wattenhofer

Abstract
Introduction to discrete event systems. We start out by studying popular models of discrete event systems. In the second part of the course
we analyze discrete event systems from an average-case and from a worst-case perspective. Topics include: Automata and Languages,

Objective
Over the past few decades the rapid evolution of computing, communication, and information technologies has brought about the
proliferation of new dynamic systems. A significant part of activity in these systems is governed by operational rules designed by humans.
The dynamics of these systems are characterized by asynchronous occurrences of discrete events, some controlled (e.g. hitting a
keyboard key, sending a message), some not (e.g. spontaneous failure, packet loss).

The mathematical arsenal centered around differential equations that has been employed in systems engineering to model and study
processes governed by the laws of nature is often inadequate or inappropriate for discrete event systems. The challenge is to develop new
modeling frameworks, analysis techniques, design tools, testing methods, and optimization processes for this new generation of systems.

In this lecture we give an introduction to discrete event systems. We start out the course by studying popular models of discrete event
systems, such as automata and Petri nets. In the second part of the course we analyze discrete event systems. We first examine discrete
event systems from an average-case perspective: we model discrete events as stochastic processes, and then apply Markov chains and
queuing theory for an understanding of the typical behavior of a system. In the last part of the course we analyze discrete event systems
from a worst-case perspective using the theory of online algorithms and adversarial queuing.

Content
1. Introduction
2. Automata and Languages
3. Simpler Automata
4. Specification Models
5. Stochastic Discrete Event Systems
6. Worst-Case Event Systems
7. Network Calculus

Lecture notes
Available
<table>
<thead>
<tr>
<th>Literature</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>[bertsekas]</td>
<td>Data Networks</td>
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<tr>
<td></td>
<td>Dimitri Bertsekas, Robert Gallager</td>
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<tr>
<td>[borodin]</td>
<td>Online Computation and Competitive Analysis</td>
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<tr>
<td></td>
<td>Allan Borodin, Ran El-Yaniv.</td>
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<td></td>
<td>Cambridge University Press, 1998</td>
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<td>[boudec]</td>
<td>Network Calculus</td>
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<td></td>
<td>J.-Y. Le Boudec, P. Thiran</td>
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<td>Springer, 2001</td>
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<tr>
<td>[cassandras]</td>
<td>Introduction to Discrete Event Systems</td>
</tr>
<tr>
<td></td>
<td>Christos Cassandras, Stéphane Lafortune</td>
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<tr>
<td>[fiat]</td>
<td>Online Algorithms: The State of the Art</td>
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<tr>
<td></td>
<td>A. Fiat and G. Woeginger</td>
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<td></td>
<td>D. Hochbaum</td>
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<tr>
<td>[schickinger]</td>
<td>Diskrete Strukturen (Band 2: Wahrscheinlichkeitstheorie und Statistik)</td>
</tr>
<tr>
<td></td>
<td>T. Schickinger, A. Steger</td>
</tr>
<tr>
<td></td>
<td>Springer, Berlin, 2001</td>
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<tr>
<td>[sipser]</td>
<td>Introduction to the Theory of Computation</td>
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<td></td>
<td>Michael Sipser</td>
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<th>227-0103-00L Control Systems</th>
<th>W</th>
<th>6 credits</th>
<th>2V+2U</th>
<th>F. Dörfler</th>
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<tr>
<td>Abstract</td>
<td>Study of concepts and methods for the mathematical description and analysis of dynamical systems. The concept of feedback. Design of control systems for single input - single output and multivariable systems.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: Signal and Systems Theory II.</td>
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<td></td>
<td>MATLAB is used for system analysis and simulation.</td>
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<tr>
<th>227-0124-00L Embedded Systems</th>
<th>W</th>
<th>6 credits</th>
<th>4G</th>
<th>L. Theile, M. Magno</th>
</tr>
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<tbody>
<tr>
<td>Abstract</td>
<td>An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. The course covers theoretical and practical aspects of embedded system design and includes a series of lab sessions.</td>
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<tr>
<td>Objective</td>
<td>Understanding architectures and components, their hardware-software interfaces, the memory architecture, communication between components, embedded operating systems, real-time scheduling theory, shared resources, low-power and low-energy design as well as hardware architecture synthesis.</td>
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<tr>
<td>Content</td>
<td>Using the formal models and methods in embedded system design in practical applications using the programming language C, the operating system FreeRTOS, a commercial embedded system platform and the associated design environment.</td>
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<td></td>
<td>An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.</td>
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<td>The focus of this lecture is on the design of embedded systems using formal models and methods as well as computer-based synthesis methods. Besides, the lecture is complemented by laboratory sessions where students learn to program in C, to base their design on the embedded operating systems FreeRTOS, to use a commercial embedded system platform including sensors, and to edit/debug via an integrated development environment.</td>
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<td></td>
<td>Specifically the following topics will be covered in the course: Embedded system architectures and components, hardware-software interfaces and memory architecture, software design methodology, communication, embedded operating systems, real-time scheduling, shared resources, low-power and low-energy design, hardware architecture synthesis.</td>
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<td></td>
<td>More information is available at <a href="https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html">https://www.tec.ee.ethz.ch/education/lectures/embedded-systems.html</a>.</td>
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</tbody>
</table>

Prerequisites / notice

- **227-0225-00L**
  - **Abstract**: Linear System Theory
  - **Objective**: Students should be able to apply the fundamental results in linear system theory to analyze and control linear dynamical systems.
  - **Content**: - Proof techniques and practices.
  - - Linear spaces, normed linear spaces and Hilbert spaces.
  - - Ordinary differential equations, existence and uniqueness of solutions.
  - - Continuous and discrete-time, time-varying linear systems. Time domain solutions. Time invariant systems treated as a special case.
  - - Controllability and observability, duality. Time invariant systems treated as a special case.
  - - Stability and stabilization, observers, state and output feedback, separation principle.
  - **Lecture notes**: Available on the course Moodle platform.
  - **Prerequisites / notice**: Sufficient mathematical maturity, in particular in linear algebra, analysis.
  - **Taught competencies**: Domain A - Subject-specific Competencies: Concepts and Theories assessed
  - Domain B - Method-specific Competencies: Techniques and Technologies assessed
  - Domain D - Personal Competencies: Critical Thinking assessed
  - Integrity and Work Ethics assessed

- **227-0247-00L**
  - **Abstract**: Power Electronic Systems I
  - **Objective**: Basics of the switching behavior, gate drive and snubber circuits of power semiconductors are discussed. Soft-switching and resonant DC/DC converters are analyzed in detail and high frequency loss mechanisms of magnetic components are explained. Space vector modulation of three-phase inverters is introduced and the main power components are designed for typical industry applications.
  - **Content**: Detailed understanding of the principle of operation and modulation of advanced power electronics converter systems, especially of zero voltage switching and zero current switching non-isolated and isolated DC/DC converter systems and three-phase voltage DC link inverter systems. Furthermore, the course should convey knowledge on the switching frequency related losses of power semiconductors and development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods. The operating behavior of isolated full-bridge DC/DC converters is detailed for different secondary side rectifier topologies; high frequency loss mechanisms of magnetic components of converter circuits are explained and approximate calculation methods are presented; the concept of space vector calculus for analyzing three-phase systems is introduced; finally, phase-oriented and space vector modulation of three-phase inverter systems are discussed related to voltage DC link inverter systems and the design of the main power components based on analytical calculations is explained.
  - **Lecture notes**: Lecture notes and associated exercises including correct answers.
  - **Prerequisites / notice**: Prerequisites: Introductory course on power electronics.

- **227-0447-00L**
  - **Abstract**: Image Analysis and Computer Vision
  - **Objective**: Overview of the most important concepts of image formation, perception and analysis, and Computer Vision. Gaining own experience through practical computer and programming exercises.
  - **Content**: This course aims at offering a self-contained account of computer vision and its underlying concepts, including the recent use of deep learning.
  - The first part starts with an overview of existing and emerging applications that need computer vision. It shows that the realm of image processing is no longer restricted to the factory floor, but is entering several fields of our daily life. First the interaction of light with matter is considered. The most important hardware components such as cameras and illumination sources are also discussed. The course then turns to image discretization, necessary to process images by computer.
  - The next part describes necessary pre-processing steps, that enhance image quality and/or detect specific features. Linear and non-linear filters are introduced for that purpose. The course will continue by analyzing procedures allowing to extract additional types of basic information from multiple images, with motion and 3D shape as two important examples. Finally, approaches for the recognition of specific objects as well as object classes will be discussed and analyzed. A major part at the end is devoted to deep learning and AI-based approaches to image analysis. Its main focus is on object recognition, but also other examples of image processing using deep neural nets are given.
  - **Lecture notes**: Course material Script, computer demonstrations, exercises and problem solutions
  - **Prerequisites / notice**: Basic concepts of mathematical analysis and linear algebra. The computer exercises are based on Python and Linux. The course language is English.

- **227-0526-00L**
  - **Abstract**: Power System Analysis
  - **Objective**: The goal of this course is understanding the stationary and dynamic problems in electrical power systems and the application of analysis tools in steady and dynamic states.
The course includes the development of stationary models of the electrical network, their mathematical representation and special characteristics and solution methods of large linear and non-linear systems of equations related to electrical power grids. Approaches such as the Newton-Raphson algorithm applied to power flow equations, superposition technique for short-circuit analysis, equal area criterion and nose curve analysis are discussed as well as power flow computation techniques for distribution grids.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>System Identification</th>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
<th>Notice</th>
<th>Prerequisites / Literature</th>
<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W 4 credits 2V+1U R. Smith</td>
<td>Theory and techniques for the identification of dynamic models from experimentally obtained system input-output data.</td>
<td>To provide a series of practical techniques for the development of dynamical models from experimental data, with the emphasis being on the development of models suitable for feedback control design purposes. To provide sufficient theory to enable the practitioner to understand the trade-offs between model accuracy, data quality and data quantity.</td>
<td>“System Identification; Theory for the User” Lennart Ljung, Prentice Hall (2nd Ed), 1999.</td>
<td>Additional papers will be available via the course Moodle.</td>
<td>Control systems (227-0216-00L) or equivalent.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Industrial Process Control</th>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
<th>Prerequisites / Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to industrial automation systems with application to the process industry, power generation as well as discrete manufacturing.</td>
<td>General understanding of industrial automation systems in different industries. Purpose, architecture, technologies, application examples, current and future trends.</td>
<td>Introduction to process automation: system architecture, data handling, communication (fieldbuses), process visualization, and engineering. Differences and characteristics of discrete and process industries. Analysis and design of open loop control problems: discrete automata, finite state machines, decision tables, and petri-nets. Practical analysis and design of closed-loop control for the process industry. Automation Engineering: Application programming in IEC 61131-3 (ladder diagrams, function blocks, sequence control, structured text); PLC programming and simulation, process visualization and operation; engineering integration from sensors, cabling, topology design, function, visualization, diagnosis, to documentation; Industry standards (e.g. OPC, Profibus); Ergonomic design, safety (IEC61508) and availability, supervision and diagnosis. Automation standards: Communication, Architecture, Engineering, dependable systems, functional safety, automation security. Extensive practical examples from different process industries, power generation, gas compressor control, and automotive manufacturing.</td>
<td>References will be given at the end of individual lectures.</td>
<td>Practical exercises will illustrate some topics, e.g. some control software coding using industry standard programming tools based on IEC61131-3.</td>
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<table>
<thead>
<tr>
<th>Abstract</th>
<th>Advanced Machine Learning</th>
<th>Objective</th>
<th>Content</th>
<th>Literature</th>
<th>Notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.</td>
<td>Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.</td>
<td>The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.</td>
<td>Topics covered in the lecture include: Fundamentals: What is data? Bayesian Learning Computational learning theory Supervised learning: Ensembles: Bagging and Boosting Max Margin methods Neural networks Unsupervised learning: Dimensionality reduction techniques Clustering Mixture Models Non-parametric density estimation Learning Dynamical Systems</td>
<td>No lecture notes, but slides will be made available on the course webpage.</td>
<td></td>
</tr>
</tbody>
</table>
The course provides an introduction to the field of human-computer interaction, emphasising the central role of the user in system design.

Through detailed case studies, students will be introduced to different methods used to analyse the user experience and shown how these can play an important role in the design of new interfaces, systems and applications.

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. Possible topics cover Probabilistic Artificial Intelligence, Computational Design and Haptic Interaction.

This seminar covers advanced topics in computer graphics, such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each time the course is offered, a collection of research papers is selected covering topics such as modeling, rendering, animation, real-time graphics, physical simulation, and computational photography. Each student presents one paper to the class and leads a discussion about the paper and related topics.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

The course website can be found here: https://teaching.siplab.org/human_computer_interaction/2021/
### Mixed Reality

**Objective**

- Understanding the foundations of 3D graphics, Computer Vision, and Human-Machine Interaction
- Have a clear understanding on how to build mixed reality apps
- Have a good overview of state-of-the-art Mixed Reality
- Be able to critically analyze and assess current research in this area.

**Content**

- Camera models and calibration, invariant features, Multiple-view geometry, Model fitting, Stereo Matching, Segmentation, 2D Shape matching, Shape from Silhouettes, Optical flow, Structure from motion, Tracking, Object recognition, Object category recognition

**Prerequisites / notice**

It is recommended that students have taken the Visual Computing lecture or a similar course introducing basic image processing concepts before taking this course.

### Physical Human Robot Interaction (pHRI)

**Objective**

The objective of this course is to give an introduction to the fundamentals of physical human robot interaction, through lectures on the underlying theoretical/mechatronics aspects and application fields, in combination with a hands-on lab tutorial. The course will guide students through the design and evaluation process of such systems.

By the end of this course, you should understand the critical elements in human-robot interactions - both in terms of engineering and human factors - and use these to evaluate and design safe and efficient assistive and rehabilitative robotic systems. Specifically, you should be able to:

1. Identify critical human factors in physical-human-robot interaction and use these to derive design requirements;
2. Compare and select mechatronic components that optimally fulfill the defined design requirements;
3. Derive a model of the device dynamics to guide and optimize the selection and integration of selected components into a functional system;
4. Design control hardware and software and implement and test human-interactive control strategies on the physical setup;
5. Characterize and optimize such systems using both engineering and psychophysical evaluation metrics;
6. Investigate and optimize one aspect of the physical setup and convey and defend the gained insights in a technical presentation.

**Content**

This course provides an introduction to fundamental aspects of physical human-robot interaction. After an overview of human haptic, visual and auditory sensing, neurophysiology and psychophysics, principles of human-robot interaction systems (kinematics, mechanical transmissions, robot sensors and actuators used in these systems) will be introduced. Throughout the course, students will gain knowledge of interaction control strategies including impedance/admittance and force control, haptic rendering basics and issues in device design for humans such as transparency and stability analysis, safety hardware and procedures. The course is organized into lectures that aim to bring students up to speed with the basics of these systems, readings on classical and current topics in physical human-robot interaction, laboratory sessions and lab visits.

Students will attend periodic laboratory sessions where they will implement the theoretical aspects learned during the lectures. Here the salient features of haptic device design will be identified and theoretical aspects will be implemented in a haptic system based on the haptic paddle (https://relab.ethz.ch/downloads/open-hardware/haptic-paddle.html), by creating simple dynamic haptic virtual environments and understanding the performance limitations and causes of instabilities (direct/virtual coupling, friction, damping, time delays, sampling rate, sensor quantization, etc.) during rendering of different mechanical properties.

**Lecture notes**

Will be distributed on Moodle before the lectures.
Biology has witnessed an unprecedented increase in experimental data and, correspondingly, an increased need for computational methods to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological Engineering approaches with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods. (iv)

Material

Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see
http://www.relab.ethz.ch/education/courses/phri.html

The lecture will be held in English.

There are 4 credit points for this lecture.

The registration is limited to 26 students.

Notice:

The registration is limited to 26 students.

There are 4 credit points for this lecture.

The lecture will be held in English.

The students are expected to have basic control knowledge from previous classes.

http://www.relab.ethz.ch/education/courses/phri.html

<table>
<thead>
<tr>
<th>Prerequisites / notice</th>
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<tbody>
<tr>
<td>Notice: The registration is limited to 26 students. There are 4 credit points for this lecture. The lecture will be held in English. The students are expected to have basic control knowledge from previous classes.</td>
</tr>
</tbody>
</table>

636-0007-00L

Computational Systems Biology

Computational Systems Biology

6 credits

3V+2U

J. Stelling

Abstract

Study of fundamental concepts, models and computational methods for the analysis of complex biological networks. Topics: Systems approaches in biology, biology and reaction network fundamentals, modeling and simulation approaches (topological, probabilistic, stoichiometric, qualitative, linear / nonlinear ODEs, stochastic), and systems analysis (complexity reduction, stability, identification).

Objective

The aim of this course is to provide an introductory overview of mathematical and computational methods for the modeling, simulation and analysis of biological networks.

Content

Biological networks have unprecedentedly increase in experimental data and, correspondingly, an increased need for computational approaches to analyze this data. The explosion of sequenced genomes, and subsequently, of bioinformatics methods for the storage, analysis and comparison of genetic sequences provides a prominent example. Recently, however, an additional area of research, captured by the label "Systems Biology", focuses on how networks, which are more than the mere sum of their parts' properties, establish biological functions. This is essentially a task of reverse engineering. The aim of this course is to provide an introductory overview of corresponding computational methods for the modeling, simulation and analysis of biological networks.

We will start with an introduction into the basic units, functions and design principles that are relevant for biology at the level of individual cells. Making extensive use of example systems, the course will then focus on methods and algorithms that allow for the investigation of biological Engineering approaches with increasing detail. These include (i) graph theoretical approaches for revealing large-scale network organization, (ii) probabilistic (Bayesian) network representations, (iii) structural network analysis based on reaction stoichiometries, (iv) qualitative methods for dynamic modeling and simulation (Boolean and piece-wise linear approaches), (v) mechanistic modeling using ordinary differential equations (ODEs) and finally (vi) stochastic simulation methods.

Lecture notes

http://www.csb.ethz.ch/education/lectures.html

Literature


Multidisciplinary Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0623-00L</td>
<td>ETH Zurich Distinguished Seminar in Robotics, Systems and Controls</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>B. Nelson, M. Chili, M. Hutter, R. Katzschmann, R. Rienner, R. Siegwart</td>
</tr>
</tbody>
</table>

Abstract

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls.

Objective

Obtain an overview of various topics in Robotics, Systems, and Controls from leaders in the field. Please see http://www.msr.ethz.ch/education/distinguished-seminar-in-robotics--systems---controls--151-0623-0.html for a list of upcoming lectures.
Content

This course consists of a series of seven lectures given by researchers who have distinguished themselves in the area of Robotics, Systems, and Controls. MSc students in Robotics, Systems, and Controls are required to attend every lecture. Attendance will be monitored. If for some reason a student cannot attend one of the lectures, the student must select another ETH or University of Zurich seminar related to the field and submit a one page description of the seminar topic. Please see http://www.msrl.ethz.ch/education/distinguished-seminar-in-robotics--systems--controls--151-0623-0.html for a suggestion of other lectures.

Prerequisites / notice

Students are required to attend all seven lectures to obtain credit. If a student must miss a lecture then attendance at a related special lecture will be accepted that is reported in a one page summary of the attended lecture. No exceptions to this rule are allowed.

► GESS Science in Perspective

see GESS Science in Perspective: Language Courses
ETH/UCZ

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MAVT.

► Semester Project

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1014-00L</td>
<td>Semester Project Robotics, Systems and Control</td>
<td>O</td>
<td>8 credits</td>
<td>17A</td>
<td>Professors</td>
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<td></td>
<td>Only for Robotics, Systems and Control MSc.</td>
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</table>

Abstract

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective

The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program.

► Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-1090-00L</td>
<td>Industrial Internship</td>
<td>O</td>
<td>8 credits</td>
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<td>external organisers</td>
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<td>Access to the company list and request for recognition under <a href="http://www.mavt.ethz.ch/praxis">www.mavt.ethz.ch/praxis</a>.</td>
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</table>

Abstract

No registration required via myStudies.

Objective

The main objective of the minimum twelve-week internship is to expose Master's students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

► Master's Thesis

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1016-00L</td>
<td>Master's Thesis Robotics, Systems and Control</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
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<td>Students who fulfill the following criteria are allowed to begin with their Master's Thesis:</td>
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<td>a. successful completion of the bachelor program;</td>
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<td>b. fulfilling of any additional requirements necessary to gain admission to the master programme;</td>
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<tr>
<td></td>
<td>c. successful completion of the semester project;</td>
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<tr>
<td></td>
<td>d. achievement of 28 ECTS in the category &quot;Core Courses&quot;.</td>
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</table>

Abstract

The Master's Thesis must be approved in advance by the tutor and is supervised by a professor of ETH Zurich or an adjunct faculty of RSC.

Objective

Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

Robotics, Systems and Control Master - Key for Type

| O   | Compulsory                          | E- | Recommended, not eligible for credits |
| W+  | Eligible for credits and recommended | Z  | Courses outside the curriculum       |
| W   | Eligible for credits                | Dr | Suitable for doctorate               |

Key for Hours

| V   | lecture                           | P  | practical/laboratory course        |
| G   | lecture with exercise              | A  | independent project                |
| U   | exercise                          | D  | diploma thesis                     |
| S   | seminar                           | R  | revision course / private study    |
| K   | colloquium                        |    |                                       |

ECTS European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
This course introduces students to the MSc STP programme. It provides a general introduction to the study of STP. This course focuses on technological innovations from the beginning of humanity through the industrial revolution up until today. It provides students with a deeper understanding of the factors that drive technological innovations, and the roles government policies, society, science, and industry play in this regard.

In a reading workshop, students will learn how to improve their skills in reading and understanding scientific papers in the English language. Presentations by invited guest speakers from academia and practice/policy. Students are assigned to play a leading role in the discussion.

A detailed programme will be sent out to the participants in advance to the course.

Literature

Literature and references will be available on Moodle.

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**Principles of Microeconomics**

**363-0503-00L**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0004-00L</td>
<td>Bridging Science, Technology, and Policy</td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
<td>T. Bernauer, T. Schmidt</td>
</tr>
</tbody>
</table>

Abstract

This course focuses on technological innovations from the beginning of humanity through the industrial revolution up until today. It provides students with a deeper understanding of the factors that drive technological innovations, and the roles government policies, society, science, and industry play in this regard.

Objective

This course picks up on the ISTP Cornerstone Science, Technology and Policy course and goes into greater depth on issues covered in that course, as well as additional issues where science and technology are among the causes of societal challenges but can also help in finding solutions.

Content

Week 1: no class because of ISTP Cornerstone Science, Technology and Policy course
Week 2: technology & society in historical perspective - technological innovations up to the industrial revolution
Week 3: technology & society in historical perspective - technological innovations during the industrial revolution - engines & electricity
Week 4: technology & society in historical perspective - from the industrial revolution to modernity - mobility and transport (railroads, ships, cars, airplanes, space)
Week 5: food production: the green revolutions.
Week 6: microelectronics, computing & the internet
Week 7: life sciences: pharmaceuticals & diagnostic technology
Week 8: energy: primary fuels, renewables, networks
Week 9: automation: self-driving cars & trains, drones
Week 10: communication & Big Data: semiconductors and software
Week 11: military & security issues associated with technological innovation
Week 12: possible futures (1): nuclear fusion, geengineering
Week 13: possible Future (2): information, communication, robotics, synthetic biology, nanotech, quantum computing

Lecture notes

Skript: Course materials will be available on moodle.

Literature

Literature: Literature and references will be available on Moodle.

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**Policy Analysis**

**860-0031-00L**

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0031-00L</td>
<td>Policy Analysis</td>
<td>O</td>
<td>4 credits</td>
<td>2V</td>
<td>T. Schmidt, B. Steffen, F. M. Egli</td>
</tr>
</tbody>
</table>

Abstract

The course Policy Analysis 1 will introduce important concepts and methods for ex-ante policy analysis. It will mostly focus on the policy content (vis-à-vis the policy process). We will primarily discuss quantitative methods. The course will contain several practical assignments in which students have to apply the concepts and methods studied.

Objective

Students should gain the skill to perform policy analyses independently. To this end, students will be enabled to understand a policy problem and the rationale for policy intervention; to select appropriate impact categories and methods to address a policy problem through policy analysis; to assess policy alternatives, using various ex-ante policy analysis methods; and to communicate the results of the analysis.

Content

The course has four major topics:
- Rationales for public policy in Science and Technology
- Impact of policies on firms and investors
- Impacts of policies on socio-technical systems
- Impacts of policies on society at large

Prerequisites / notice

Open to anyone from ETH

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**Cornerstone Science, Technology, and Policy**

**860-0000-00L**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0000-00L</td>
<td>Cornerstone Science, Technology, and Policy</td>
<td>O</td>
<td>2 credits</td>
<td>1S</td>
<td>T. Bernauer</td>
</tr>
</tbody>
</table>

Abstract

This course introduces students to the MSc STP programme. It provides a general introduction to the study of STP.

Objective

This course introduces students to the MSc program in two ways. First, it provides a general introduction to the study of STP. Second, it exposes students to various complex policy problems and ways and means of coming up with proposals for and assessments of policy options.

Content

- Introduction to Science, Technology and Policy
- Reading Workshop: Reading and understanding scientific papers in English language

Lecture notes

Skript: Course materials will be available on moodle.

Literature

Literature: Literature and references will be available on Moodle.

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**Colloquium Science, Technology, and Policy (HS)**

**860-0003-00L**

<table>
<thead>
<tr>
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<th>Lecturers</th>
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<tr>
<td>860-0003-00L</td>
<td>Colloquium Science, Technology, and Policy (HS)</td>
<td>O</td>
<td>1 credit</td>
<td>2K</td>
<td>T. Schmidt, T. Bernauer</td>
</tr>
</tbody>
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Abstract

Presentations by invited guest speakers from academia and practice/policy. Students are assigned to play a leading role in the discussion and write a report on the respective event.

Objective

Presentations by invited guest speakers from academia and practice/policy. Students are assigned to play a leading role in the discussion and write a report on the respective event.

Content

See the program on the ISTP website: http://www.istp.ethz.ch/events/colloquium.html

Prerequisites / notice

Open to anyone from ETH
The learning objectives of the course are:

(1) Students must be able to discuss basic principles, problems and approaches in microeconomics. (2) Students can analyse and explain simple economic principles in a market using supply and demand graphs. (3) Students can contrast different market structures and describe firm and consumer behaviour. (4) Students can identify market failures such as externalities related to market activities and illustrate how these affect the economy as a whole. (5) Students can also recognize behavioural failures within a market and discuss basic concepts related to behavioural economics. (6) Students can apply simple mathematical concepts on economic problems.

Topics covered by the course are:

- Supply and demand
- Consumer demand: neoclassical and behavioural perspective
- Cost of production: neoclassical and behavioural perspective
- Welfare economics, deadweight losses
- Governmental policies
- Market failures, common resources and public goods
- Public sector, tax system
- Market forms (competitive, monopolistic, monopolistic competitive, oligopolistic)
- International trade
- International trade

This course introduces students to the necessary fundamentals of statistics, and its application, to understand policy. Theoretically the course will provide a survey of foundational concepts and techniques statistics and mathematics. The applied part of the course will focus on implementing these techniques in R, as well as developing the practical skills required to be able to independently conduct data based research projects.

By doing so, students will gain a familiarity with foundational concepts and techniques in statistics, and be able to apply these to new problems. Students will also develop the requisite skills to be able to independently conduct a variety of tasks in R, such as data cleaning, visualisation and analysis. Finally, students will be able to produce summaries of statistical analyses that non-specialists can understand.
Abstract
This lecture series sets up an agenda for widening the disciplinary field of architecture and urbanism from their focus on the city, or the urban in the narrow sense, to wider territorial scales, which correspond to the increasing scales of contemporary urbanisation. It discusses the concepts of territory and urbanisation, and their implications for the work of architects and urbanists.

Objective
The course will enable students to critically discuss concepts of territory and urbanisation. It will invite students to revisit the history of architects' work engaging with the problematic of urbanising territories and territorial organisation. The goal is to motivate and equip students to engage with territory in the present day and age, by setting out our contemporary urban agenda.

Content
Within the theme My Species, the four guest speakers engaged in fields ranging from art and landscape representation to bioethics and environmental philosophy, will approach territory through the notions such as multispecies, coexistence, and diversity. With a more-than-human perspective on the territory, the guest speakers will elaborate their take on “telling horrible stories in beautiful ways,” debate “the dignity of plants,” expound upon “mankind's fascination to better the world,” and confer “the non-human turn” and what is to come after.

23. 09. 2021
On Territory
MILICA TOPALOVIĆ

30. 09. 2021
Architecture and Urbanisation
MILICA TOPALOVIĆ

07. 10. 2021
Methods in Territorial Research and Design
MILICA TOPALOVIĆ

14. 10. 2021
Multispecies Worldbuilding
Guest lecture by FEIFEI ZHOU

21. 10. 2021
Better Nature
Guest lecture by ALEXANDRA DAISY GINSBERG

04. 11. 2021
Planetary Urbanisation: Hinterland
MILICA TOPALOVIĆ

11. 11. 2021
Tomatoes Talk, Birch Trees Learn – Do Plants Have Dignity?
Guest lecture by FLORIANNE KOECHLIN

18. 11. 2021
Disappearance of the Countryside
MILICA TOPALOVIĆ

25. 11. 2021
What is Soul? On the Idea of Species Being
Guest lecture by OXANA TIMOFEEVA

09. 12. 2021
Our Common Territories: An Outlook
MILICA TOPALOVIĆ

Prerequisites / notice
The lectures will take place on Thursdays, 10.00-12.00, at ONA Fokushalle E7 and on ZOOM.

Lecturer:
Prof. Milica Topalovic

Team:
Prof. Milica Topalović, Nazlı Tümerdem, Vesna Jovanović

Contact:
Nazlı Tümerdem
tuemerdem@arch.ethz.ch

Our website:
https://topalovic.arch.ethz.ch

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Communication | assessed |
| | Self-presentation and Social Influence | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Self-awareness and Self-reflection | assessed |

701-1453-00L Ecological Assessment and Evaluation
W 3 credits 3G F. Knaus

Abstract
The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.

Objective
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation
4) perform an ecological evaluation project from the field survey up to the decision making and planning.
The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems. In the first part, I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014).

The objective of this course is to provide an overview of the entire infrastructure management process. The high-level process described can be used as a starting point to ensure that infrastructure management is done professionally, efficiently and effectively. It also enables a clear understanding of where computer systems can be used to help automate parts of the process. Students can use this process to help improve the specific infrastructure management processes in the organisations in which they work in the future.

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More specifically upon completion of the course, students will:

- understand the main tasks of an infrastructure manager and the complexity of these tasks,
- understand the importance of setting goals and constraints in the management of infrastructure,
- be able to predict the deterioration of individual assets using discrete states that are often associated with visual inspections,
- be able to develop and evaluate simple management strategies for individual infrastructure assets,
- be able to develop and evaluate intervention programs that are aligned with their strategies,
- understand the principles of guiding projects and evaluating the success of projects,
- be able to formally model infrastructure management processes, and
- understand the importance of evaluating the infrastructure management process and have a general idea of how to do so.
The weekly lectures are structured as follows:

1. Introduction: An introduction to infrastructure management, with emphasis on the consideration of the benefits and costs of infrastructure to all members of society, and balancing the need for predictability and analysis effort. The expectations of your throughout the semester, including a description of the project.

2. Setting goals and constraints – To manage infrastructure you need to know what you expect from it in terms of service and how much you are willing to pay for it. We discuss the measures of service for this purpose, as well as the ideas of quantifiable and non-quantifiable benefits, proxies of service, and valuing service.

3. Predicting the future – As infrastructure and our expectations of service from it change over time, these changes need to be included in the justification of management activities. This we discuss the connection between provided service and the physical state of the infrastructure and one way to predict their evolution over time.

4. Help session 1

5. Determining and justifying general interventions - It is advantageous to be able to explain why infrastructure assets need to be maintained, and not simply say that they need to be maintained. This requires explanation of the types of interventions that should be executed and how these interventions will achieve the goals. It also requires explaining which interventions are to be done if it is not possible to do everything due to for example budget constraints. This week we cover how to determine optimal intervention strategies for individual assets, and how to convert these strategies into network level intervention programs.

6. Help session 2

7. Determining and justifying monitoring – Once it is clear how infrastructure might change over time, and the optimal intervention strategies are determined, you need to explain how you are going to know that these states exist. This requires the construction of monitoring strategies for each of asset. This week we focus on how to develop monitoring strategies that ensure interventions are triggered at the right time.

8. Converting programs to projects / Analysing projects – Once programs are completed and approved, infrastructure managers must create, supervise and analyse projects. This week we focus on this conversion and the supervision and analysis of projects.

9. Help session 3 and submission of project report.

The course uses a combination of qualitative and quantitative approaches. The quantitative analysis required in the project requires at least 12 weeks of intimate knowledge of the use of Excel. Some students, however, prefer to use Python or R.

### Literature

The lecture materials will be distributed via Moodle two days before each lecture.

- The lecture materials consist of handouts, the slides, and example calculations in Excel.
- The lecture materials will be distributed via Moodle two days before each lecture.

### Prerequisites / notice

Appropriate literature will be handed out when required via Moodle.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
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<tr>
<td></td>
<td>Decision-making</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td></td>
<td>Project Management</td>
<td>assessed</td>
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<td>Domain D - Personal Competencies</td>
<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Integrity and Work Ethics</td>
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<td></td>
<td>Self-direction and Self-management</td>
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### Exercises

The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

### Content

- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies
- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

### Literature

A script and presentation slides for each exercise will be provided on Moodle.

**Autumn Semester 2021**

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**Domain B - Method-specific Competencies**

- Techniques and Technologies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

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**Domain C - Social Competencies**

- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

---

**Domain D - Personal Competencies**

- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

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**103-0347-01L Landscape Planning and Environmental Systems (GIS W Exercises)**

- 3 credits
- 2U
- A. Grêt-Regamey, C. Brouillet, N. Klein

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**Abstract**

The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).

**Objective**

- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies

**Content**

- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

**Lecture notes**

A script and presentation slides for each exercise will be provided on Moodle.
Abstract
In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

Objective
The aims of this course are:
1) To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2) To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3) To show the importance of ecosystem services.
4) To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5) To identify and measure the characteristics of landscape.
6) Learn how to use spatial data in landscape planning.

Content
In this course, the following topics are discussed:
- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

Lecture notes
No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice
The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.
Objective
Public transport is a key driver for making our cities more livable, clean and accessible, providing safe, and sustainable travel options for millions of people around the globe. Proper planning of public transport system also ensures that the system is competitive in terms of speed and cost. Public transport is a crucial asset, whose social, economic and environmental benefits extend beyond those who use it regularly; it reduces the amount of cars and road infrastructure in cities; reduces injuries and fatalities associated to car accidents, and gives transport accessibility to very large demographic groups.

Goal of the class is to understand the main characteristics and differences of public transport networks. Their various performance criteria based on various perspective and stakeholders. The most relevant decision making problems in a planning tactical and operational point of view

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate possible improvements to existing networks of public transport and the management of those networks; optimize the use of resources in public transport.

General structure:
- general introduction of transport, modes, technologies,
- system design and line planning for different situations,
- mathematical models for design and line planning
- timetabling and tactical planning, and related mathematical approaches
- operations, and quantitative support to operational problems,
- evaluation of public transport systems.

Content
- Basics for line transport systems and networks
- Passenger/Supply requirements for line operations
- Objectives of system and network planning, from different perspectives and users, design dilemmas
- Conceptual concepts for passenger transport: long-distance, urban transport, regional, local transport

Planning process, from demand evaluation to line planning to timetables to operations
- Matching demand and modes
- Line planning techniques
- Timetabling principles
- Allocation of resources
- Management of operations
- Measures of realized operations
- Improvements of existing services

Lecture notes
- Lecture slides are provided.

Literature
- Ceder, Avi: Public Transit Planning and Operation, CRC Press, 2015, ISBN 978-1466563919 (English)
Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

The lecture introduces necessary basic knowledge and is based on the following main topics:

- Inward development and challenges of spatial transformation
- Planning approaches and The (political) steering of spatial development
- Interplay of formal and informal processes and processes across different scales of spatial development
- Methods of action-oriented planning in situations of insecurity
- Integrated space and infrastructure development
- Different types of participation in spatial development

By taking up the lecture, the students are able to recognize cross-scale, complex tasks of spatial development and transformation and to use their theoretical, methodical and professional knowledge to clarify them.

Students are introduced to a narrative of 'Urban Stories' through a series of three tools driven by social, governance, and environmental assessment. Creative Thinking Urban Design III - Planning approaches and political organization in Switzerland

Further information and the documents for the lecture can be found on the homepage of IRL/STL

Further information and the documents for the lecture can be found on the homepage of IRL/STL

Domain A - Subject-specific Competencies

- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Domain C - Social Competencies

- Cooperation and Teamwork

Domain D - Personal Competencies

- Critical Thinking
- Self-direction and Self-management

Objective

Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

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- Cooperation and Teamwork

Domain D - Personal Competencies

- Critical Thinking
- Self-direction and Self-management

Lecture notes

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Domain A - Subject-specific Competencies

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- Project Management

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- Cooperation and Teamwork

Domain D - Personal Competencies

- Critical Thinking
- Self-direction and Self-management

052-0707-00L

Urban Design III

W 2 credits 2V

H. Klumpner, M. Fessel

Students are introduced to a narrative of 'Urban Stories' through a series of three tools driven by social, governance, and environmental transformations in today's urbanization processes. Each lecture explores one city's spatial and organizational ingenuity born out of a particular place's realities, allowing students to transfer these inventions into a catalog of conceptual tools.

How can students of architecture become active agents of change? What does it take to go beyond a building's scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and understand existing urban phenomena activating them in a design process? The lecture series produces a growing catalog of operational urban tools across the globe, considering Governance, Social, and Environmental realities. Instead of limited binary comparing of cities, we are building a catalog of change, analyzing what design solutions cities have been developing informally incrementally over time, why, and how.

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How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

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In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

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The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

The course aims to teach students how to evaluate a design project from the perspective of the end user. The concept of evidence-based design is introduced, and complemented with theoretical background on space syntax and spatial cognition. This is a project-oriented course, students implement a range of methods on a sample project. The course is tailored for architecture design students.

This mechanical engineering course focuses on the technical aspects of wind turbines; non-technical issues are not within the scope of this course. On completion of this course, the student shall be able to conduct the preliminary aerodynamic and structural analysis of the wind turbine blades. The student shall also be more aware of the broad context of drivetrains, dynamics and control, electrical systems, and meteorology, relevant to all types of wind turbines.

The course is tailored for students studying for B-ARCH and M-ARCH degrees. As an alternative to obtaining D-GESS credit, architecture students can obtain course credit in "Vertiefungsfach" or "Wahlfach".

### Energy and Mobility

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-0216-00L</td>
<td>Wind Energy</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>N. Chokani</td>
</tr>
<tr>
<td>Abstract</td>
<td>The objective of this course is to introduce the students to the fundamentals, technologies, modern day application, and economics of wind energy. These subjects are introduced through a discussion of the basic principles of wind energy generation and conversion, and a detailed description of the broad range of relevant technical, economic and environmental topics.</td>
<td></td>
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<tr>
<td>Objective</td>
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</tr>
<tr>
<td>Content</td>
<td>This mechanical engineering course focuses on the technical aspects of wind turbines; non-technical issues are not within the scope of this technically oriented course. On completion of this course, the student shall be able to conduct the preliminary aerodynamic and structural design of the wind turbine blades. The student shall also be more aware of the broad context of drivetrains, dynamics and control, electrical systems, and meteorology, relevant to all types of wind turbines.</td>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>227-0731-00L</td>
<td>Power Market I - Portfolio and Risk Management</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>D. Reichelt, G. A. Koepell</td>
</tr>
<tr>
<td>Abstract</td>
<td>Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
| Content        | 1. Pan-European power market and trading  
1.1. Power trading  
1.2. Development of the European power markets  
1.3. Energy economics  
1.4. Spot and OTC trading  
1.5. European energy exchange EEX  
2. Market model  
2.1. Market place and organisation  
2.2. Balance groups / balancing energy  
2.3. Ancillary services  
2.4. Market for ancillary services  
2.5. Cross-border trading  
2.6. Capacity auctions  
3. Portfolio and Risk management  
3.1. Portfolio management 1 (introduction)  
3.2. Forward and futures contracts  
3.3. Risk management 1 (m2m, VaR, hpfc, volatility, cVaR)  
3.4. Risk management 2 (PaR)  
3.5. Contract valuation (HPFC)  
3.6. Portfolio management 2  
2.8. Risk Management 3 (enterprise wide)  
4. Energy & Finance I  
4.1. Options 1 basics  
4.2. Options 2 hedging with options  
4.3. Introduction to derivatives (swaps, cap, floor, collar)  
4.4. Financial modelling of physical assets  
4.5. Trading and hydro power  
4.6. Incentive regulation |

Lecture notes: Handouts of the lecture  
Prerequisites / notice: 1 excursion per semester, 2 case studies, guest speakers for specific topics.  
Course Moodle: https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636
This course is an introduction to urban and regional economics. It focuses on the formation and development of urban systems, and highlight how transport infrastructure investments can affect the location, size and composition of such systems.

Objective
The main objective of this course is to provide students with some basic tools to analyze the fundamental economic forces at play in urban systems (i.e., agglomeration and congestion forces), and the role of transport networks in shaping the structure of these systems. Why do urban areas grow or decline? How do transport networks affect the location of individuals and firms? Does the location of a firm determine its productivity? Can transport infrastructure investments reduce economic disparities? These are some of the questions that students should be able to answer after having completed the course.

Content
The course is organized in four parts. I start with the key observation that economic activity (both in terms of population density and productivity) is unevenly distributed in space. For instance, the share of the population living in urban centers is increasing globally, from 16% in 1900 and 50% in 2000 to about 68% by the year 2050 (UN, World Economic Prospects, 2014). The goal of the first part is then to understand the economic forces at play behind these trends, looking at the effects within and across urban areas. I will also discuss how natural or man-made geographical characteristics (e.g., rivers, mountains, borders, etc.) affect the development of such urban systems.

In the second part, I discuss the planning and pricing of transport networks, moving from simple local models to more complex transport models at a global scale. The key aspects include: the first and second best road pricing, the public provision of transport networks and the demographic effects of transport networks.

In the third part, I combine the previous two parts and analyze the interaction between urban systems and transportation. Thereby, the main focus is to understand the economic mechanisms that can lead to a general equilibrium of all actors involved. However, as the study of the historical development of urban systems and transport networks provides interesting insights, I will discuss how their interaction in the past shapes today’s economic geography.

Finally, I broaden the scope of the course and explore related topics. There will be a particular emphasis on the relation between urban systems and fiscal federalism as well as environmental policies. Both aspects are important determinants of the contemporary developments of urban systems, and as such deserve our attention.

In general, this class focuses on the latest research developments in urban and regional economics, though it does not require prior knowledge in this field. It pays particular attention to economic approaches, which are based on theoretical frameworks with strong microfoundations and allow for precise policy recommendations.

Lecture notes
Course slides will be made available to students prior to each class.

Literature
Course slides will be made available to students.

151-0163-00L Nuclear Energy Conversion

| W | 4 credits | 2V+1U | A. Manera |

Abstract
Physical fundamentals of the fission reaction and the sustainable chain reaction, thermal design, construction, function and operation of nuclear reactors and power plants, light water reactors and other reactor types, conversion and breeding

Objective
Students get an overview on energy conversion in nuclear power plants, on construction and function of the most important types of nuclear reactors with special emphasis to light water reactors. They obtain the mathematical/physical basis for quantitative assessments concerning most relevant aspects of design, dynamic behaviour as well as material and energy flows.

Content
Nuclear physics of fission and chain reaction. Thermodynamics of nuclear reactors. Design of the reactor core. Introduction into the dynamic behaviour of nuclear reactors. Overview on types of nuclear reactors, difference between thermal reactors and fast breeders. Construction and operation of nuclear power plants with pressurized and boiling water reactors, role and function of the most important safety systems, special features of the energy conversion. Development tendencies of reactor technology.

Lecture notes
Hand-outs will be distributed. Additional literature and information on the website of the lab: https://www.ethz.ch/content/special/interest/mavt/energy-technology/lab-of-nuclear-energy-systems/en/studium/teaching-materials/151-0163-00l-nuclear-energy-conversion.html

Literature

R. L. Murray: Nuclear Energy (Sixth Edition), An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, Elsevier

151-1633-00L Energy Conversion

| W | 4 credits | 3G | I. Karlin, G. Sansavini |

Abstract
This course is intended for students outside of D-MAVT.

This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies.

Objective
Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students’ intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included.

Content
1. Thermodynamic systems, states and state variables
2. Properties of substances: Water, air and ideal gas
3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy
4. Second law of thermodynamics and entropy
5. Energy analysis of steam power cycles
6. Energy analysis of gas power cycles
7. Refrigeration and heat pump cycles
8. Nonideal gas equation of state and Joule-Thomson effect
9. Maximal work and exergy
10. Mixtures
11. Chemical reactions and combustion systems; chemical and phase equilibrium

Lecture notes
Lecture slides and supplementary documentation will be available online.

Literature

Prerequisites / notice
This course is intended for students outside of D-MAVT.

Students are assumed to have an adequate background in calculus, physics, and engineering mechanics.
### Taught Competencies

#### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

#### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

#### Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

#### Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

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### 151-0567-00L Engine Systems

**W 4 credits 3G C. Onder**

**Abstract**
Introduction to current and future engine systems and their control systems

**Objective**
Introduction to methods of control and optimization of dynamic systems. Application to real engines. Understand the structure and behavior of drive train systems and their quantitative descriptions.

**Content**
- Physical description and mathematical models of components and subsystems (mixture formation, load control, supercharging, emissions, drive train components, etc.).
- Case studies of model-based optimal design and control of engine systems with the goal of minimizing fuel consumption and emissions.

**Lecture notes**
Introduction to Modeling and Control of Internal Combustion Engine Systems

*Guzzella Lino, Onder Christopher H.*
ISBN: 978-3-642-10774-0

**Prerequisites / notice**
Combined homework and testbench exercise (air-to-fuel-ratio control or idle-speed control) in groups

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### 227-0122-00L Introduction to Electric Power Transmission: System & Technology

**W 4 credits 2V+2U C. Franck, G. Hug**

**Abstract**
Introduction to theory and technology of electric power transmission systems.

**Objective**
At the end of this course, the student will be able to: describe the structure of electric power systems, name the most important components and describe what they are needed for, apply models for transformers and overhead power lines, explain the technology of transformers and lines, calculate stationary power flows and other basic parameters in simple power systems.

**Content**
- Structure of electric power systems, transformer and power line models, analysis of and power flow calculation in basic systems, technology and principle of electric power systems.
- Lecture script in English, exercises and sample solutions.

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### 227-0665-00L Battery Integration Engineering

**W 3 credits 2V+1U T. J. Patey**

**Priority given to Electrical and Mechanical Engineering students**

*Students are required to have attended one of the following courses:*
- 227-0664-00L Technology and Policy of Electrical Energy Storage
- 529-0440-00L Physical Electrochemistry and Electrocatalysis
- 529-0191-01L Renewable Energy Technologies II, Energy Storage and Conversion
- 529-0659-00L Electrochemistry (Exception for PhD students).
Batteries enable sustainable mobility, renewable power integration, various power grid services, and residential energy storage. Linked with low cost PV, Li-ion batteries are positioned to shift the 19th-century centralized power grid into a 21st-century distributed one. As with battery integration, this course combines understanding of electrochemistry, heat & mass transfer, device engineering.

The learning objectives are:
- Apply critical thinking on advancements in battery integration engineering. Assessment reflects this objective and is based on review of a scientific paper, with mark weighting of 10 / 25 / 65 for a proposal / oral presentation / final report, respectively.
- Design battery system concepts for various applications in the modern power system and sustainable mobility, with a deep focus on replacing diesel buses with electric buses combined with charging infrastructure.
- Critically assess progresses in battery integration engineering: from material science of novel battery technologies to battery system design.
- Apply "lessons learned" from the history of batteries to assess progress in battery technology.
- Apply experimental and physical concepts to develop battery models in order to predict lifetime.
- Battery systems for the modern power grid and sustainable mobility.
- Battery lifetime modeling by aging, thermal, and electric sub-models.
- Electrical architecture of battery energy storage systems.
- History and review of electrochemistry & batteries, and metrics to assess future developments in electrochemical energy storage.
- Sustainability and life cycle analysis of battery system innovations.

Prerequisites / notice
Limited to 30 Students. Priority given to Electrical and Mechanical Engineering students.

Mandatory - background knowledge in batteries & electrochemistry acquired in one of the following courses:
- 227-0664-00L Technology and Policy of Electrical Energy Storage
- 529-1440-00L Physical Electrochemistry and Electroanalytical
- 529-0191-01L Renewable Energy Technologies II, Energy Storage and Conversion
- 529-0659-00L Electrochemistry

Exception given for PhD students

Data and Computer Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>263-3210-00L</td>
<td>Deep Learning</td>
<td>W</td>
<td>8 credits</td>
<td>3V+2U+2A</td>
<td>F. Perez Cruz, A. Lucchi</td>
</tr>
</tbody>
</table>

Abstract
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

Objective
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.

Prerequisites / notice
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:
  - Advanced Machine Learning
    https://ml2.inf.ethz.ch/courses/aml/
  - Computational Intelligence Lab
    http://da.inf.ethz.ch/teaching/2019/CIL/
  - Introduction to Machine Learning
    https://ias.inf.ethz.ch/teaching/introml-S19
  - Statistical Learning Theory
    http://ml2.inf.ethz.ch/courses/slt/
  - Computational Statistics
    https://stat.ethz.ch/lectures/ss19/comp-stats.php
  - Probabilistic Artificial Intelligence
    https://las.inf.ethz.ch/teaching/pai-f18

252-1414-00L | System Security            | W    | 7 credits | 2V+2U+2A | S. Capkun, A. Perrig |

Abstract
The first part of the lecture covers individual system aspects starting with tamperproof or tamper-resistant hardware in general over operating system related security mechanisms to application software systems, such as host based intrusion detection systems. In the second part, the focus is on system design and methodologies for building secure systems.

Objective
In this lecture, students learn about the security requirements and capabilities that are expected from modern hardware, operating systems, and other software environments. An overview of available technologies, algorithms and standards is given, with which these requirements can be met.
Content

The first part of the lecture covers individual system's aspects starting with tamperproof or tamperresistant hardware in general over operating system related security mechanisms to application software systems such as host based intrusion detection systems. The main topics covered are: tamper resistant hardware, CPU support for security, protection mechanisms in the kernel, file system security (permissions / ACLs / network filesystem issues), IPC Security, mechanisms in more modern OS, such as Capabilities and Zones, Libraries and Software tools for security assurance, etc.

In the second part, the focus is on system design and methodologies for building secure systems. Topics include: patch management, common software faults (buffer overflows, etc.), writing secure software (design, architecture, QA, testing), compiler-supported security, language-supported security, logging and auditing (BSM audit, dtrace, ...), cryptographic support, and trustworthy computing (TGG, SGX).

Along the lectures, model cases will be elaborated and evaluated in the exercises.

<table>
<thead>
<tr>
<th>263-4640-00L</th>
<th>Network Security</th>
<th>W</th>
<th>8 credits</th>
<th>2V+2U+3A</th>
<th>A. Perrig, S. Frei, M. Legner, K. Paterson</th>
</tr>
</thead>
</table>

Abstract

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to attack end systems. This course provides an in-depth study of network attack techniques and methods to defend against them.

- Students are familiar with fundamental network-security concepts.
- Students can assess current threats that Internet services and networked devices face, and can evaluate appropriate countermeasures.
- Students can identify and assess vulnerabilities in software systems and network protocols.
- Students have an in-depth understanding of a range of important state-of-the-art security technologies.
- Students can implement network-security protocols based on cryptographic libraries.

Content

The course will cover topics spanning four broad themes with a focus on the first two themes:

1. network defense mechanisms such as public-key infrastructures, TLS, VPNs, anonymous-communication systems, secure routing protocols, secure DNS systems, and network intrusion-detection systems;
2. network attacks such as hijacking, spoofing, denial-of-service (DoS), and distributed denial-of-service (DDoS) attacks;
3. analysis and inference topics such as traffic monitoring and network forensics; and
4. new technologies related to next-generation networks.

In addition, several guest lectures will provide in-depth insights into specific current real-world network-security topics.

Prerequisites / notice

This lecture is intended for students with an interest in securing Internet communication services and network devices. Students are assumed to have knowledge in networking as taught in a communication networks lecture like 252-0064-00L or 227-0120-00L. Basic knowledge of information security or applied cryptography as taught in 252-0211-00L or 263-4660-00L is beneficial, but an overview of the most important cryptographic primitives will be provided at the beginning of the course.

The course will involve several graded course projects. Students are expected to be familiar with a general-purpose or network programming language such as C/C++, Go, Python, or Rust.

Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Decision-making</td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
<td>assessed</td>
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<td></td>
<td>Problem-solving</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Project Management</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
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<td></td>
<td>Customer Orientation</td>
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<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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</tbody>
</table>

252-0535-00L Advanced Machine Learning

Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.
Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

Fundamentals:
What is data?
Bayesian Learning
Computational learning theory

Supervised learning:
Ensembles: Bagging and Boosting
Max Margin methods
Neural networks

Unsupervised learning:
Dimensionality reduction techniques
Clustering
Mixture Models
Non-parametric density estimation
Learning Dynamical Systems

Lecture notes
No lecture notes, but slides will be made available on the course webpage.

Literature


Prerequisites / notice
The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

263-2400-00L
Reliable and Trustworthy Artificial Intelligence
W
6 credits
2V+2U+1A
M. Vechev

Abstract
Creating reliable and explainable probabilistic models is a fundamental challenge to solving the artificial intelligence problem. This course covers some of the latest and most exciting advances that bring us closer to constructing such models.

Objective
The main objective of this course is to expose students to the latest and most exciting research in the area of explainable and interpretable artificial intelligence, a topic of fundamental and increasing importance. Upon completion of the course, the students should have mastered the underlying methods and be able to apply them to a variety of problems.

To facilitate deeper understanding, an important part of the course will be a group hands-on programming project where students will build a system based on the learned material.

Content
This comprehensive course covers some of the latest and most important research advances (over the last 3 years) underlying the creation of safe, trustworthy, and reliable AI (more information here: https://www.sri.inf.ethz.ch/teaching/reliableai21):

* Adversarial Attacks on Deep Learning (noise-based, geometry attacks, sound attacks, physical attacks, autonomous driving, out-of-distribution)
* Defenses against attacks
* Combining gradient-based optimization with logic for encoding background knowledge
* Complete Certification of deep neural networks via automated reasoning (e.g., via numerical relaxations, mixed-integer solvers).
* Probabilistic certification of deep neural networks
* Training deep neural networks to be provably robust via automated reasoning
* Fairness (different notions of fairness, certifiably fair representation learning)
* Federated Learning (introduction, security considerations)

Prerequisites / notice
While not a formal requirement, the course assumes familiarity with basics of machine learning (especially linear algebra, gradient descent, and neural networks as well as basic probability theory). These topics are usually covered in "Intro to ML" classes at most institutions (e.g., "Introduction to Machine Learning" at ETH).

For solving assignments, some programming experience in Python is expected.

263-3845-00L
Data Management Systems
W
8 credits
3V+1U+3A
G. Alonso

Abstract
The course will cover the implementation aspects of data management systems using relational database engines as a starting point to cover the basic concepts of efficient data processing and then expanding those concepts to modern implementations in data centers and the cloud.

Objective
The goal of the course is to convey the fundamental aspects of efficient data management from a systems implementation perspective: storage, access, organization, indexing, consistency, concurrency, transactions, distribution, query compilation vs interpretation, data representations, etc. Using conventional relational engines as a starting point, the course will aim at providing an in depth coverage of the latest technologies used in data centers and the cloud to implement large scale data processing in various forms.

Content
The course will first cover fundamental concepts in data management: storage, locality, query optimization, declarative interfaces, concurrency control and recovery, buffer managers, management of the memory hierarchy, presenting them in a system independent manner. The course will place an special emphasis on understanding these basic principles as they are key to understanding what problems existing systems try to address. It will then proceed to explore their implementation in modern relational engines supporting SQL to then expand the range of systems used in the cloud: key value stores, geo-replication, query as a service, serverless, large scale analytics engines, etc.

Literature
The main source of information for the course will be articles and research papers describing the architecture of the systems discussed.

The list of papers will be provided at the beginning of the course.

Prerequisites / notice
The course requires to have completed the Data Modeling and Data Bases course at the Bachelor level as it assumes knowledge of databases and SQL.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

assessed
Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.

This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical and deep learning approaches.

The course covers the following topics:

1. To introduce the fundamental problems of computer vision.
2. To introduce the main concepts and techniques used to solve those.
3. To enable participants to implement solutions for reasonably complex problems.
4. To enable participants to make sense of the computer vision literature.

Biocompatible Materials

The course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Each lecturer will first give an overview of the state-of-the-art in his/her field, and then describe the research highlights in his/her own research group. While preparing their Final Projects and discussing them in front of the class, the students will deepen their understanding of how to apply a range of new technologies to solve specific scientific problems and technical challenges. Exposure to the different frontiers will also improve their ability to conduct effective nanoscale research, recognize the broader significance of their work and to start collaborations.

Starting with the fabrication and analysis of nanoparticles and nanostructured materials that enable a variety of scientific and technical applications, we will transition to discussing biological nanosystems, how they work and what bioinspired engineering principles can be derived, to finally discussing biomedical applications and potential health risk issues. Scientific aspects as well as the many of the emerging technologies will be covered that start impacting so many aspects of our lives. This includes new phenomena in physics, advanced materials, novel technologies and new methods to address major medical challenges.

The course covers the following topics:

1. Introduction into molecular characteristics of molecules involved in the materials-to-biology interface. Molecular design of biomaterials.
2. The concept of biocompatibility.
3. Introduction into methodology used in biomaterials research and application.
4. Introduction to different material classes in use for medical applications.

Life Science and Health

Materials and Mechanics in Medicine

Understanding of physical and technical principles in biomechanics, biomaterials, and tissue engineering as well as a historical perspective. Mathematical description and problem solving. Knowledge of biomedical engineering applications in research and clinical practice.

Frontiers in Nanotechnology

Many disciplines are meeting at the nanoscale, from physics, chemistry to engineering, from the life sciences to medicine. The course will prepare students to communicate more effectively across disciplinary boundaries, and will provide them with deep insights into the various frontiers.

The goal of the course is to give Master and Graduate students from all interested departments an overview of what nanotechnology is all about, from analytical techniques to nanosystems, from physics to biology. Students will start to appreciate the extent to which scientific communities are meeting at the nanoscale. They will learn about the specific challenges and what is currently sizzling in the respective fields, and learn the vocabulary that is necessary to communicate effectively across departmental boundaries.

Bio compatible Materials

Introduction to molecules used for biomaterials, molecular interactions between different materials and biological systems (molecules, cells, tissues). The concept of bio compatibility is discussed and important techniques from biomaterials research and development are introduced.

Prerequisites / notice

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.
Introduction into natural and polymeric biomaterials used for medical applications. The concepts of biocompatibility, biodegradation and the consequences of degradation products are discussed on the molecular level. Different classes of materials with respect to potential applications in tissue engineering, drug delivery and for medical devices are introduced. Strong focus lies on the molecular interactions between materials having very different bulk and/or surface chemistry with living cells, tissues and organs. In particular the interface between the materials surfaces and the eukaryotic cell surface and possible reactions of the cells with an implant material are elucidated. Techniques to design, produce and characterize materials in vitro as well as in vivo analysis of implanted and explanted materials are discussed.

A link between academic research and industrial entrepreneurship is demonstrated by external guest speakers, who present their current research topics.

Handouts are deposited online (moodle).

Lecture notes

Literature

(available online via ETH library)

Handouts and references therein.

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**Translational Science for Health and Medicine**

**W** 3 credits 2G  J. Goldhahn, C. Wolfrum

**Abstract**
Translational science is a cross disciplinary scientific research that is motivated by the need for practical applications that help people. The course should help to clarify basics of translational science, illustrate successful applications and should enable students to integrate key features into their future projects.

**Objective**
After completing this course, students will be able to understand:
- Principles of translational science (including project planning, ethics application, basics of resource management and interdisciplinary communication)

**Content**
- What is translational science and what is it not?
- How to identify need?
- Disease concepts and consequences for research
- Basics about incidence, prevalence etc., and orphan indications
- How to choose the appropriate research type and methodology
- Ethical considerations including ethics application
- Pros and cons of different types of research
- Coordination of complex approaches incl. timing and resources
- How to measure success?
- Outcome variables
- Improving the translational process
- Challenges of communication?
- How independent is translational science?
- Academic boundary conditions vs. industrial influences

Positive and negative examples will be illustrated by distinguished guest speakers.

**Literature**


**Domain A - Subject-specific Competencies**
- Concepts and Theories: assessed

**Domain B - Method-specific Competencies**
- Analytical Competencies: assessed
- Decision-making: assessed
- Problem-solving: not assessed
- Project Management: not assessed

**Domain C - Social Competencies**
- Communication: not assessed
- Cooperation and Teamwork: not assessed

**Domain D - Personal Competencies**
- Creative Thinking: not assessed
- Critical Thinking: assessed

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**Epidemiology and Prevention**

**W** 3 credits 2V  M. Puhan, R. Heusser

**Abstract**
The module Epidemiology and prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

**Objective**
The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware on how epidemiological facts are used in prevention, practice and politics.

**Content**
The module Epidemiology and prevention follows an overall framework that describes the course of scientific discovery from the detection of a disease to the development of prevention and treatment interventions and their evaluation in clinical trials and real world settings. We will discuss study designs in the context of existing knowledge and the type of evidence needed to advance knowledge. Examples from nutrition, chronic and infectious diseases will be used in order to show the underlying concepts and methods.

**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories
- Domain B - Method-specific Competencies: Analytical Competencies
- Domain C - Social Competencies: Communication
- Domain D - Personal Competencies: Creative Thinking

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**Public Health Concepts**

**W** 3 credits 2V  R. Heusser

**Abstract**
The module "public health concepts" offers an introduction to key principles of public health. Students learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

**Objective**
At the end of this module students are able:
- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

**Content**
Concepts of descriptive and analytical epidemiology, study designs, measures of effect, confounding and bias, screening, surveillance, definition of health and health promotion, health dimensions and health determinants, prevention strategies, public health interventions, public health action cycle, epidemiology and prevention of infectious and chronic diseases (HIV, COVID-19, Obesity, Iodine/PH nutrition).

**Taught competencies**
- Domain A - Subject-specific Competencies: Concepts and Theories
- Domain B - Method-specific Competencies: Analytical Competencies

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**Stem Cells: Biology and Therapeutic Manipulation**

**W** 4 credits 3G  T. Schroeder

**Abstract**
Stem cells are central in tissue regeneration and repair, and hold great potential for therapy. We will discuss the role of stem cells in health and disease, and possibilities to manipulate their behavior for therapeutic application. Basic molecular and cell biology, engineering and novel technologies relevant for stem cell research and therapy will be discussed.

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Objective
Understanding of current knowledge, and lack thereof, in stem cell biology, regenerative medicine and required technologies. Theoretical preparation for practical laboratory experimentation with stem cells.

Content
We will use different diseases to discuss how to potentially model, diagnose or heal them by stem cell based therapies. This will be used as a guiding framework to discuss relevant concepts and technologies in cell and molecular biology, engineering, imaging, bioinformatics, tissue engineering, that are required to manipulate stem cells for therapeutic application.

Topics will include:
- Embryonic and adult stem cells and their niches
- Induced stem cells by directed reprogramming
- Relevant basic cell biology and developmental biology
- Relevant molecular biology
- Cell culture systems
- Cell fates and their molecular control by transcription factors and signalling pathways
- Cell reprogramming
- Disease modelling
- Tissue engineering
- Bioimaging, Bioinformatics
- Single cell technologies

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<th>Lecturers</th>
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<td>376-0225-00L</td>
<td>Physical Activities and Health</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Knols, E. de Bruin, further speakers</td>
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Abstract
This course introduces/explores the complex relationship between physical activity, sedentary behavior and health. It will discuss the evolution of current physical activity recommendations. It will examine the current evidence base that has informed physical activity recommendations and that identified physical activity as a key modifiable lifestyle behavior contributing to disease and mortality.

Objective
On completion of this course students will be able to demonstrate:
2. Thorough knowledge and critical awareness of current recommendations for physical activity, and current prevalence and trends of physical activity and associated diseases.
3. Awareness of current national and international physical activity policies and how these impact on global challenges.

Content
Introduction to Physical Activity for Health, including sedentary behavior
- Physical activity epidemiology: concepts principles and approaches
- Physical activity and all cause morbidity and mortality
- Physical activity and chronic disease: Coronary heart disease, diabetes, bone health, cancer and obesity
- Physical activity and brain health
- Physical activity and sedentary behavior recommendations
- Population prevalence of physical activity and sedentary behavior
- Physical activity policies
- Physical activity assessment

Literature
Core texts for this course are:

Prerequisites / notice
From the BSc-course the following book is recommended: ‘Essentials of strength training and conditioning’ T. Baechle, R. Earle (3rd Edition)

Resources and Environment

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<tr>
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<tr>
<td>103-0347-00L</td>
<td>Landscape Planning and Environmental Systems</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Grêt-Regamey</td>
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Abstract
In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

Objective
The aims of this course are:
1. To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2. To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3. To show the importance of ecosystem services.
4. To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5. To identify and measure the characteristics of landscape.
6. Learn how to use spatial data in landscape planning.

Content
In this course, the following topics are discussed:
1. Definition of the concept of landscape
2. Relevance of landscape planning
3. Landscape metrics
4. Landscape change
5. Methods, instruments and aims of landscape planning (policy)
6. Socio-political questions of the future
7. Environmental systems, ecological connectivity
8. Ecosystem services
9. Urban landscape services
10. Practice of landscape planning

Lecture notes
No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice
The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Media and Digital Technologies assessed
- Problem-solving assessed
- Project Management assessed

Domain C - Social Competencies
- Communication assessed
- Cooperation and Teamwork not assessed
- Customer Orientation not assessed
- Leadership and Responsibility not assessed
- Self-presentation and Social Influence not assessed
- Sensitivity to Diversity not assessed
- Negotiation not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility not assessed
- Creative Thinking assessed
- Critical Thinking assessed
- Integrity and Work Ethics not assessed
- Self-awareness and Self-reflection not assessed
- Self-direction and Self-management not assessed

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<tr>
<td>651-4057-00L</td>
<td>Climate History and Palaeoclimatology</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>H. Stoll, I. Hernández Almeida, H. Zhang</td>
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Abstract
Climate history and palaeoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors that lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is there evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of a sea level higher than modern, and by how much? What lessons do these have for the future?
4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems? Will mean climate change El Nino frequency and intensity? What factors drive climate change in mid and high latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

701-1341-00L Water Resources and Drinking Water | W | 3 | 2G | S. Hug, M. Berg, F. Hammes, U. von Gunten |

Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The underlying principles, assets and trade-offs of the different approaches are introduced, and students work in a number of small projects with these models to gain first-hand experience.

Objective
Students will
- be able to understand, assess and evaluate the fundamental properties of dynamic systems using vegetation models as case studies
- obtain an overview of dynamic modelling techniques from the individual plant to the global level
- understand the basic assumptions of the various model types, which dictate the skill and limitations of the respective model
- be able to work with such model types on their own
- appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.

701-1677-00L Quantitative Vegetation Dynamics: Models from Tree to Globe | W | 3 | 3G | H. Lischke, U. Hiltner, B. Rohner |

Abstract
This course provides hands-on experience with models of vegetation dynamics across temporal and spatial scales. The underlying principles, assets and trade-offs of the different approaches are introduced, and students work in a number of small projects with these models to gain first-hand experience.

Objective
Students will
- be able to understand, assess and evaluate the fundamental properties of dynamic systems using vegetation models as case studies
- obtain an overview of dynamic modelling techniques from the individual plant to the global level
- understand the basic assumptions of the various model types, which dictate the skill and limitations of the respective model
- be able to work with such model types on their own
- appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems.
Models of individuals
- Deriving single-plant models from inventory measurements
- Plant models based on "first principles"

Models at the stand scale
- Simple approaches: matrix models
- Competition for light and other resources as central mechanisms
- Individual-based stand models: distance-dependent and distance-independent
- Theoretical models

Models at the landscape scale
- Simple approaches: cellular automata
- Dispersal and disturbances (windthrow, fire, bark beetles) as key mechanisms
- Landscape models

Global models
- Sacrificing local detail to attain global coverage: processes and entities
- Dynamic Global Vegetation Models (DGVMs)
- DGVMs as components of Earth System Models

Handouts will be available in the course and for download
Will be indicated at the beginning of the course
Will be given according to the lessons. Partially integration of e-learning tools.

Models of individuals
Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss

Abstract
Geological and mineralogical aspects to important non-metallic mineral resources. Industrial use of specific mineral resources as well as

Objective
Students will learn to understand the use of non-metallic mineral resources from a geological and mineralogical point of view as well as

Content
Teaching, case-studies and exercises (e.g. raw-material industry).
Course "Applied mineralogy and non-metallic resources I" (autumn/winter semester):
Non-metallic resources. Occurrences, geology, extraction, properties, fabrication and use. Industrial aspects, (new) technologies, market, stock, situation, reserves & sources, trends and development, environmental aspects, law.

Chapters: e.g. coal/carbon (coal, graphite, diamond, fullerene); oil/gas (oil- and tarsands, oil-shirts); phosphates/nitrates; aluminum (bauxite, corundum); salt; carbonates; titanium; clay and clay minerals; sulphur; gypsum/anhydrite; fluorite; asbestos; talc; micas; rare earth elements.

Course "Applied mineralogy and non-metallic resources II" (fall/summer semester):

Chapters: e.g. Stone industry - technical aspects of building stones, properties, weathering, treatment, quarries, products. Crushed stones - quarries, products, planning, environment. Gravel an sand - resources/reserves, environment (protection/law), alternative products (substitution). Cement and concrete (geological resources, prospection, fabrication, environment).

Will be given according to the lessons. Partially integration of e-learning tools.

Number of participants limited to 100
Priority is given to the target groups: Bachelor and Master Environmental Sciences and PhD Environmental Sciences until September 21st, 2021.
Waiting list will be deleted October 1st, 2021.

Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Will be identified based on the chosen topic.
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

The course content of the lecture Landscape Planning and Environmental Systems (103-0347-00 V) will be illustrated in practical GIS exercises (e.g. habitat modelling, land use change, ecosystem services, connectivity).
Objective
- Practical application of theory from the lectures
- Quantitative assessment and evaluation of landscape characteristics
- Learning useful applications of GIS for landscape planning
- Developing landscape planning measures for practical case studies

Content
- Applications of GIS in landscape planning
- Landscape analysis
- Landscape structural metrics
- Modelling habitats and land use change
- Calculating urban ecosystem services
- Ecological connectivity

Lecture notes
A script and presentation slides for each exercise will be provided on Moodle.

Literature
Will be named in the lecture.

Prerequisites / notice
Basic GIS skills are strongly recommended.

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | not assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies | assessed |
| Domain C - Social Competencies | Analytical Competencies | assessed |
| | Decision-making | not assessed |
| | Media and Digital Technologies | assessed |
| | Problem-solving | assessed |
| | Project Management | assessed |
| Domain D - Personal Competencies | Communication | assessed |
| | Cooperation and Teamwork | assessed |
| | Customer Orientation | not assessed |
| | Leadership and Responsibility | not assessed |
| | Self-presentation and Social Influence | not assessed |
| | Sensitivity to Diversity | not assessed |
| | Negotiation | not assessed |
| | Adaptable and Flexible | assessed |
| | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | not assessed |
| | Self-awareness and Self-reflection | not assessed |
| | Self-direction and Self-management | not assessed |

701-1253-00L Analysis of Climate and Weather Data

Abstract
An introduction into methods of statistical data analysis in meteorology and climatology. Applications of hypothesis testing, extreme value analysis, evaluation of deterministic and probabilistic predictions, principal component analysis. Participants understand the theoretical concepts and purpose of methods, can apply them independently and know how to interpret results professionally.

Objective
Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. They can conduct such analyses independently, and they develop an attitude of scrutiny and an awareness of uncertainty when interpreting results. Participants improve skills in understanding technical literature that uses modern statistical data analyses.

Content
The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Lecture notes
Documentation and supporting material:
- slides used during the lecture
- exercise sets and solutions
- R-packages with software and example datasets for workshop sessions

All material is made available via the lecture web-page.

Literature
For complementary reading:

Prerequisites / notice
Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (incl linear regression) (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

701-1551-00L Sustainability Assessment

Abstract
The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

Number of participants limited to 35.

Waiting list will be deleted October 1st, 2021.

No enrollment possible after October 1st, 2021.
Objective

At the end of the course, students:
- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making

Content

The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

Lecture notes

Handouts are provided

Literature

Selected scientific articles and book-chapters

Prerequisites / notice

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking

701-1257-00L European Climate Change W 3 credits 2G C. Schär, J. Rajczak, S. C. Scherrer

Abstract

The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
- observational datasets, observation and detection of climate change;
- underlying physical processes and feedbacks;
- numerical and statistical approaches;
- currently available projections.

Objective

At the end of this course, participants should:
- understand the key physical processes shaping climate change in Europe;
- know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
- be familiar with relevant observational and modeling data sets;
- be able to tackle simple climate change questions using available data sets.

Content

Contents:
- global context
- observational data sets, analysis of climate trends and climate variability in Europe
- global and regional climate modeling
- statistical downscaling
- key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects
- projections of European and Alpine climate change

Lecture notes

Slides and lecture notes will be made available at http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice

Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

Case Studies

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>860-0011-00L</td>
<td>Agent-Based Modeling and Social System Simulation</td>
<td>W</td>
<td>6</td>
<td>2S+2A</td>
<td>N. Antulov-Fantulin, T. Asikis, D. Helbing</td>
</tr>
</tbody>
</table>

Prerequisites: Good mathematical skills, basic programming skills, elementary probability and statistics.

Abstract

This course introduces mathematical and computational models to study techno-socio-economic systems and the process of scientific research.

Students develop a significant project to tackle techno-socio-economic challenges in application domains of complex systems. They are expected to implement a model and communicating their results through a seminar thesis and a short oral presentation.

Objective

The students should be able to implement simulation models and document their skills through a seminar thesis and finally give a short oral presentation.

Content

Students are expected to implement themselves models of various social processes and systems, including agent-based models, complex networks models, decision making, group dynamics, human crowds, or game-theoretical models.

Part of this course will consist of supervised programming exercises. Credit points are finally earned for the implementation of a mathematical or empirical model from the complexity science literature and the documentation in a seminar thesis.

Lecture notes

The lecture slides will be presented on the course web page after each lecture.
Agent-Based Modeling
https://link.springer.com/chapter/10.1007/978-3-642-24004-1_2

Social Self-Organization

Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Pedestrian, Crowd, and Evacuation Dynamics
https://www.research-collection.ethz.ch/handle/20.500.11850/45424

The hidden geometry of complex, network-driven contagion phenomena (relevant for modeling pandemic spread)
https://science.sciencemag.org/content/342/6164/1337

Further literature will be recommended in the lectures.

The number of participants is limited to the size of the available computer teaching room. The source code related to the seminar thesis should be well enough documented.

Good programming skills and a good understanding of probability & statistics and calculus are expected.

Prerequisites / notice

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Customer Orientation not assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed
Negotiation assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Abstract
The course provides the necessary knowledge to develop models supporting and also evaluating the solution of given planning problems. The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis.

Objective
- Knowledge and understanding of statistical methods and algorithms commonly used in transport planning
- Comprehend the reasoning and capabilities of transport models
- Ability to independently develop a transport model able to solve / answer planning problem
- Getting familiar with cost-benefit analysis as a decision-making supporting tool

To cope with that, the problem is divided into sub-problems, which are solved using various statistical models (e.g. regression, discrete choice analysis) and algorithms (e.g. iterative proportional fitting, shortest path algorithms, method of successive averages).

The course is composed of a lecture part, providing the theoretical knowledge, and an applied part in which students develop their own models in order to evaluate a transport project/ policy by means of cost-benefit analysis. Interim lab session take place regularly to guide and support students with the applied part of the course.

Lecture notes
Moodle platform (enrollment needed)

Literature


Cooperation and Conflict Over International Water Resources, In-Depth Case Study
860-0012-01L

Only for Science, Technology, and Policy MSc and PhD students.

Prerequisite: you have to be enrolled in 860-0012-00L
Students write an individual term paper on technical, economic, and political water challenges in an international context. Coached by one of the instructors, students develop and write a case study that examines ways and means to address a specific challenge, and to evaluate success or failure of international collaboration.

In developing their individual term paper, the students broaden their overview of (1) causes and consequences of water scarcity and water pollution problems in an international context; (2) they assess concepts and policies to mitigate a specific water challenge, and (3) they analyze determinants of success or failure of international collaboration in the water sectors.

In the basic course on Cooperation and Conflict... 860-0012-00L the students acquire basic knowledge on contentious issues in managing international water resources, on the determinants of cooperation and conflict over international water issues, and on ways and means of mitigating conflict and promoting cooperation.

In this course, which is reserved to STP students, the participants will be individually coached by one of the instructors and do research and develop a case-study paper on an international water challenge of their choice. The topic should avoid overlap with the work in course 860-0012-00L.

In a global context, the targets of sustainable development goal 6 serve as a possible starting point: http://bit.ly/2yVARMG

In the European context, the implementation reports of the Water Framework Directive represent another reference frame: http://bit.ly/2ySNPLI

This is a research seminar at the Master level. PhD students are also welcome.

This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Ability to (1) understand the causes and consequences of water scarcity and water pollution problems in large international river systems; (2) understand ways and means of addressing such water challenges; and (3) analyse when and why international efforts in this respect succeed or fail.

Based on lectures and discussion of scientific papers and reports, students acquire basic knowledge on contentious issues in managing international water resources, on the determinants of cooperation and conflict over international water issues, and on ways and means of mitigating conflict and promoting cooperation. Students will then, in small teams coached by the instructors, carry out research on a case of their choice (i.e. an international river basin where riparian countries are trying to find solutions to water allocation and/or water quality problems associated with a large dam project). They will write a brief paper and present their findings towards the end of the semester.

In this course, which is reserved to STP students, the participants will be individually coached by one of the instructors and do research and develop a case-study paper on an international water challenge of their choice. The topic should avoid overlap with the work in course 860-0012-00L.

STP students should sign up for both courses, 860-0012-00L and 860-0012-01L.

This course is reserved for STP students who participate in the basic course on Cooperation and Conflict Over International Water Resources 860-0012-00L.

ISTP students who take this course should also register for the course 860-0012-01L - Cooperation and conflict over international water resources; In-depth case study.
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of choice, using your insights from Discovering Management.

Students have the option to either write this alone or in a group of two students.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

Domain A - Subject-specific Competencies
- Concepts and Theories

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
- Creative Thinking
- Critical Thinking

The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

The grade will be determined by a final exam.

The theory sessions will be assessed via a multiple choice exam.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and/or appreciate the challenges that entrepreneurs and managers deal with.

The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Primarily suited for Master and PhD level.

This course addresses the role of policy and its underlying politics in the transformation of the energy sector. It covers historical, socioeconomic, and political perspectives and applies various theoretical concepts to understand specific aspects of the governance of the energy transition.

Domain A - Subject-specific Competencies
- Concepts and Theories

Domain B - Method-specific Competencies
- Analytical Competencies
- Problem-solving

Domain C - Social Competencies
- Communication

Domain D - Personal Competencies
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This lecture introduces the social and environmental challenges involved in the energy sector and discusses the implications of these challenges for the rate and direction of technical change in the energy sector. It compares the current situation with historical socio-technical transitions and derives the consequences for policy-making. It introduces theoretical frameworks and concepts for studying innovation and transitions. It then focuses on the role of policy and policy change in governing the energy transition, considering the role of political actors, institutions and policy feedback.

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Domain B - Method-specific Competencies
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- Problem-solving

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All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle. These course materials will form the point of departure for the lectures, class discussions and team work.

Primarily suited for Master and PhD level.
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Does not take place this semester.

Information and application: http://sparklabs.ch/

During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials.

The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students will learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session.

Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

### 857-0027-00L International Organizations (Field Trip)

**Abstract**
A two-day field trip to international organizations in Geneva - e.g., the World Trade Organization, the World Health Organization and the International Committee of the Red Cross.

**Objective**
Become familiar with the work and challenges of international organizations based in Geneva.

**Literature**

**Prerequisites / notice**
Teams of 2-3 students prepare a 2-3 page background reading for the group on a specific international organization and lead the discussion with representatives of that organization during the visit.

### 860-0023-00L International Environmental Politics

**Abstract**
This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

**Objective**
The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

**Content**
This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

**Lecture notes**
Assigned reading materials and slides will be available via Moodle.

**Literature**
Assigned reading materials and slides will be available via Moodle.
This course introduces students to key methods for quantitative policy impact evaluation and covers the different stages of the research process. Students should be able to:

- understand the basics of public opinion research
- translate this theoretical knowledge into the practical design and implementation of surveys
- make use of survey experiments for causal inference

At the end of the course, students should be able to use and evaluate public opinion data and design survey experiments to test policy-relevant questions.

### 860-0034-00L Designing and Implementing Public Opinion Surveys and Experiments

**Abstract**

This course teaches the basics of public opinion surveys. We start with the theoretical foundations of the formation of public opinion, public opinion formation and ideology, then turn to the practical lessons of developing and implementing own surveys with a focus on causal inference via survey experiments. Finally, we give practical insights into the analysis of complex survey data.

**Objective**

The goals of this class are:

- to understand the basics of public opinion research
- to translate this theoretical knowledge into the practical design and implementation of surveys
- to make use of survey experiments for causal inference

### 865-0008-00L Policy Evaluation and Applied Statistics

**Abstract**

This course introduces students to key methods for quantitative policy impact evaluation and covers the different stages of the research process. Acquired skills are applied in a self-selected project applying experimental methods. Students also learn how to perform simple statistical analyses with the statistical Software R.

**Objective**

Students should be able to:

- know strategies to test causal hypotheses using experimental methods and regression analysis.
- are able to formulate and implement a research design for a particular policy question and a particular type of data.
- are able to critically read and assess published studies on policy evaluation.
- are able to use the statistical software R for data analysis.
- can apply all the steps involved in a policy impact evaluation.

**Content**

Policy impact evaluation employs a wide variety of research methods, such as statistical analysis of secondary data, surveys or laboratory and field experiments. The course will begin with an overview of the various methodological approaches, including their advantages and disadvantages and the conditions under which their use is appropriate. It will continue with a discussion of the different stages of a policy impact evaluation, including hypothesis generation, formulating a research design, measurement, sampling, data collection and data analysis. For data analysis, linear regression models will be revised, with a focus on difference-in-differences methods, regression discontinuity design and randomized controlled trials used for policy evaluation. Students, who already have a solid background in these methods can skip these sessions.

Throughout the course, students will work on a self-selected project on a suitable topic. In addition, students will have to solve bi-weekly assignments.

### 701-1631-00L Foundations of Ecosystem Management

**Abstract**

This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It explores case studies of ecosystem management approaches and considers their practicability, their achievements and possible barriers to their uptake.

**Objective**

Students should be able to:

a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales.

b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

**Content**

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental wellbeing. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give considerable consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

**Lecture notes**

No Script

**Literature**


Abstract
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will reflect on the question of how democracy could be digitally upgraded to promote innovation, sustainability, and resilience.

Objective
To collect credit points, students will have to give a 30-40 minute presentation in the seminar, after which the presentation will be discussed. The presentation will be graded.

Content
This seminar will present speakers who discuss the challenges and opportunities arising for our cities and societies with the digital revolution. Besides discussing questions of automation using Big Data, AI and other digital technologies, we will also reflect on the question of how democracy could be digitally upgraded, and how citizen participation could contribute to innovation, sustainability, resilience, and quality of life. This includes questions around collective intelligence and digital platforms that support creativity, engagement, coordination and cooperation.

Literature
Martin Treiber and Arne Kesting
Traffic Flow Dynamics: Data, Models and Simulation

Dirk Helbing
Traffic and related self-driven many-particle systems
Reviews of Modern Physics 73, 1067
https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.73.1067

Dirk Helbing
An Analytical Theory of Traffic Flow (collection of papers)
https://www.researchgate.net/publication/261629187

Michael Batty, Kay Axhausen et al.
Smart cities of the future
Books by Michael Batty
https://link.springer.com/article/10.1140/epjst/e2012-01703-3

How social influence can undermine the wisdom of crowd effect
https://www.pnas.org/content/108/22/9020

Evidence for a collective intelligence factor in the performance of human groups
https://science.sciencemag.org/content/330/6004/686.full

Optimal incentives for collective intelligence
https://www.pnas.org/content/114/20/5077.short

Collective Intelligence: Creating a Prosperous World at Peace
https://www.amazon.com/Collective-Intelligence-Creating-Prosperous-World/dp/097156616X/

Big Mind: How Collective Intelligence Can Change Our World
https://www.amazon.com/Big-Mind-Collective-Intelligence-Change/dp/0691170797/

Programming Collective Intelligence
https://www.amazon.com/Programming-Collective-Intelligence-Building-Applications/dp/0596529325/

Urban architecture as connective-collective intelligence. Which spaces of interaction?
https://www.mdpi.com/2071-1050/5/7/2928

Build digital democracy
https://www.nature.com/news/society-build-digital-democracy-1.18690

How to make democracy work in the digital age
http://www.huffingtonpost.com/entry/how-to-make-democracy-work-in-the-digital-age_us_57a2f488e4b0456cb7e17e0f

Digital Democracy: How to make it work?
http://futurict.blogspot.com/2020/06/digital-democracy-how-to-make-it-work.html

Proof of witness presence: Blockchain consensus for augmented democracy in smart cities

Iterative Learning Control for Multi-agent Systems Coordination
https://www.amazon.co.uk/Iterative-Learning-Control-Multi-agent-Coordination-ebook/dp/B06XJVQC41/ref=sr_1_1?dchild=1&keywords=coordination+jennings+multi-agent&qid=1601973480&sr=8-1-fkmr1

Decentralized Collective Learning for Self-managed Sharing Economies
https://dl.acm.org/doi/abs/10.1145/3277668

Further literature will be recommended in the lectures.
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

Computational Social Science

Number of participants limited to 50.

W 3 credits 2S

D. Helbing, J. Argota Sánchez-Vaquerizo, M. Korecki

Abstract
The seminar aims at three-fold integration: (1) bringing modeling and computer simulation of techno-socio-economic processes and phenomena together with related empirical, experimental, and data-driven work, (2) combining perspectives of different scientific disciplines (e.g. sociology, computer science, physics, complexity science, engineering), (3) bridging between fundamental and applied work.

Objective
Participants of the seminar should understand how tightly connected systems lead to networked risks, and why this can imply systems we do not understand and cannot control well, thereby causing systemic risks and extreme events.

They should also be able to explain how systemic instabilities can be understood by changing the perspective from a component-oriented to an interaction- and network-oriented view, and what fundamental implications this has for the proper design and management of complex dynamical systems.

Computational Social Science and Global Systems Science serve to better understand the emerging digital society with its close co-evolution of information and communication technology (ICT) and society. They make current theories of crises and disasters applicable to the solution of global-scale problems, taking a data-based approach that builds on a serious collaboration between the natural, engineering, and social sciences, i.e. an interdisciplinary integration of knowledge.

Literature

Computational Social Science
https://science.sciencemag.org/content/sci/323/5915/721.full.pdf

Manifesto of Computational Social Science
https://link.springer.com/article/10.1140/epjst/e2012-01697-8

Social Self-Organisation

How simple rules determine pedestrian behaviour and crowd disasters
https://www.pnas.org/content/108/17/6884.short

Peer review and competition in the Art Exhibition Game
https://www.pnas.org/content/113/30/8414.short

Generalized network dismantling
https://www.pnas.org/content/116/14/6554.short

Computational Social Science: Obstacles and Opportunities
https://science.sciencemag.org/content/369/6507/1060?rss=1=bit

Bit by Bit: Social Research in the Digital Age
https://www.amazon.co.uk/Bit-Social-Research-Digital-Age-ebook/dp/B072MPFXX2/

Further literature will be recommended in the lectures.
## Taught competencies

### Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

### Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

### Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

### Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: assessed
- Self-direction and Self-management: assessed

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>W</th>
<th>2G</th>
<th>L.</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>363-0537-00L</td>
<td>Resource and Environmental Economics</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>3 credits</td>
</tr>
<tr>
<td></td>
<td>Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>L. Bretscher</td>
</tr>
</tbody>
</table>

### Abstract

A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

### Content

The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

### Literature


Autumn Semester 2021

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Communication

Objective

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 30 to 40 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

This course is about all that. The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

There will be daily reading assignments, which we will then discuss critically during the class sessions. All of these will be posted in PDF format on a course Moodle. In addition, there will be two books to be read over the course of the semester. Both of these can be accessed from the ETH library or in PDF form free of charge. They are:

The Climate Casino, by William Nordhaus. Yale University Press.


Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving not assessed

Domain C - Social Competencies
Communication not assessed
Negotiation not assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed

Literature

Urban Design III

052-0707-00L

Autumn Semester 2021

Students are introduced to a narrative of ‘Urban Stories’ through a series of three tools driven by social, governance, and environmental transformations in today’s urbanization processes. Each lecture explores one city’s spatial and organizational ingenuity born out of a particular place’s realities, allowing students to transfer these inventions into a catalog of conceptual tools.

Abstract

How can students of architecture become active agents of change? What does it take to go beyond a building’s scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we discover, set rather than follow trends and make decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, particular place’s realities, allowing students to transfer these inventions into a catalog of conceptual tools.

Objective

How can students of architecture become active agents of change? What does it take to go beyond a building’s scale, making design-relevant decisions to the city rather than a single client? How can we design in cities with a lack of land, tax base, risk, and resilience, understanding that Zurich is the exception and these other cities are the rule? How can we consider how and how to what extent they can be relevant in other places. Urban Stories is the basic practice of architecture and urban design. It introduces a repertoire of urban design instruments to the students to use, test, and start their designs.
The thesis should demonstrate the students ability to conduct independent research on the basis of the theoreticel and methodological

Internship - Long

Urban form cannot be reduced to physical space. Cities result from social construction, under the influence of technologies, ecology, culture, the impact of experts, and accidents. Urban un-concluded processes respond to political interests, economic pressure, cultural inclinations, along with the imagination of architects and urbanists and the informal powers at work in complex adaptive systems. Current urban phenomena are the result of urban evolution. The facts stored in urban environments include contributions from its entire lifecycle, visible in the physical environment, and non-physical aspects. This imaginary city exists along with its potentials and problems and with the conflicts that have evolved. Knowledge and understanding, along with a critical observation of the actions and policies, are necessary to understand the diversity and instability present in the contemporary city and understand how urban form evolved to its current state.

How did cities develop into the cities we live in now? Urban plans, instruments, visions, political decisions, economic reasonings, cultural inputs, and social organization have been used to operate in urban settlements in specific moments of change. We have chosen cities that exemplify how these instruments have been implemented and how they have shaped urban environments. We transcribe these instruments into urban operational tools that we have recognized and collected within existing tested cases in contemporary cities across the globe.

This lecture series will introduce urban knowledge and the way it has introduced urban models and operational modes within different concrete realities, therefore shaping cities. The lecture series translates urban knowledge into operational tools, extracted from cities where they have been tested and become exemplary samples, most relevant for understanding how the urban landscape has taken shape. The tools are clustered in twelve thematic clusters and three tool scales for better comparability and cross-reflection.

The Tool case studies are compiled into a global urbanization toolbox, which we use as typological models to read the city and critically reflect upon it. The presented contents are meant to serve as inspiration for positioning in future professional life and provide instruments for future design decisions.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

The internship serves to make students familiar with policy analysis in a real world setting, for instance in a government agency, a NGO, a regulatory or public affairs division of a private sector firm, or a consulting firm focused on policy analysis.

The long internship corresponds to a workload of 360 hours, to be accomplished within 6 months. The internship can be started the earliest in the second semester. The internship needs to be approved by the study director. Therefore students need to hand in a short description to the study secretary before they start the internship.

In an interview with a local designer, we measure our insights against the most pressing design topics in cities today, including inclusion, affordable housing, provision of public spaces, and infrastructure for all.

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**Internship**

The performance counts as electives.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
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<tr>
<td>860-0600-00L</td>
<td>Internship - Short</td>
<td>W</td>
<td>6 credits</td>
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<td>external organisers</td>
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<td></td>
<td>The internship can be started the earliest in the second semester. The internship needs to be approved by the study director. Therefore students need to hand in a short description to the study secretary before they start the internship.</td>
<td></td>
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</tr>
<tr>
<td>Abstract</td>
<td>The internship is a voluntary part of the MSc curriculum.</td>
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</tr>
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</tr>
<tr>
<td>Content</td>
<td>The short internship corresponds to a workload of 180 hours, to be accomplished within 3 months.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The internship can be started the earliest in the second semester. The internship needs to be approved by the study director. Therefore students need to hand in a short description to the study secretary before they start the internship.</td>
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<tr>
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<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>860-0700-00L</td>
<td>Internship - Long</td>
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<td>12 credits</td>
<td></td>
<td>external organisers</td>
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<td>Objective</td>
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</tr>
<tr>
<td>Content</td>
<td>The long internship corresponds to a workload of 360 hours, to be accomplished within 6 months.</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>The internship can be started the earliest in the second semester. The internship needs to be approved by the study director. We ask students to hand in a short description to the study secretary before they start the internship.</td>
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</tbody>
</table>

**Master's Thesis**

Only students who fulfill the following criteria are allowed to begin with their master thesis:

- a. successful completion of the bachelor programme;
- b. fulfilling of any additional requirements necessary to gain admission to the master programme.

The thesis should demonstrate the students ability to conduct independent research on the basis of the theoreticel and methodological knowledge acquired during the MSc program.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>860-0900-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Professors</td>
</tr>
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</table>

Science, Technology, and Policy Master - Key for Type

<table>
<thead>
<tr>
<th></th>
<th>Compulsory</th>
<th>Eligible for credits and recommended</th>
<th>Eligible for credits</th>
<th>Recommended, not eligible for credits</th>
<th>Courses outside the curriculum</th>
<th>Suitable for doctorate</th>
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<tbody>
<tr>
<td>O</td>
<td>E</td>
<td>Z</td>
<td>Dr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Recommended</td>
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### Key for Hours

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<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
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</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ECTS**
- European Credit Transfer and Accumulation System
- Special students and auditors need special permission from the lecturers.
### Educational Science

Course offerings in the category Educational Science are listed under "Programme: Educational Science for Teaching Diploma and TC".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>851-0240-15L</td>
<td>Designing Educational Environments in Physical</td>
<td>O</td>
<td>4</td>
<td>2S</td>
<td>H. Gubelmann, R. Scharpf</td>
</tr>
<tr>
<td></td>
<td>Education (EW2 Sport)</td>
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<tr>
<td></td>
<td>Compulsory course requirements for EW2 Sport: This course is required to be taken prior to EW4 Sport &quot;Outdoor Education: Concepts and Practice&quot; (851-0242-06L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Abstract     | Students learn principles of teaching beyond classroom and regular PE-Lessons:  
|              | - Planning and organizing camps and events  
|              | - Teaching the "Ergänzungsfach"  
|              | As a practical part students design the Outdoor event in EW4 of the following term |
| Objective    | Students know  
|              | - How to plan events and camps  
|              | - To assess curricula critically and to use them properly  
|              | - How to combine theoretical and practical issues in the ‘Ergänzungsfach’ |
| Content      | 1. LV Semestereinführung  
|              | 2. LV Planung Outdoor-Weekend  
|              | 3. LV Auswertung Outdoor-Event  
|              | 4. LV Planung Event  
|              | 5. LV Event-Präsentationen / Schlussveranstaltung |
| Prerequisites | EW2 is compulsory requirement for EW4 Sport    |      |      |       |                                |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td></td>
<td>This lecture is only apt for students who intend to enrol in the programs &quot;Teaching Diploma&quot; or &quot;Teaching Certificate&quot;. It is about learning in childhood and adolescence.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>This course looks into scientific theories and also empirical studies on human learning and relates them to the school.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.</td>
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</tr>
</tbody>
</table>
| Content      | Themenatische Schwerpunkte:  
|              | Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfers; Lernen durch Instruktion und Erklärungen; Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen  
| Lecture notes | Foliern werden zur Verfügung gestellt. |
| Prerequisites | This lecture is only apt for students who intend to enrol in the programs "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence. |

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurm</td>
</tr>
</tbody>
</table>
|              | Number of participants limited to 30  
|              | This course unit can only be enrolled after successful participation in, or during enrollment in the course "Human Learning (EW1)". |
| Abstract     | Literature from the learning sciences is critically discussed with a focus on research methods.  
|              | At the first meeting, working groups will be assembled and meetings with those will be set up.  
|              | In the small groups students will write critical essays about the read literature. At the third meeting, we will discuss the essays and develop research questions in group work. |
| Objective    | - Understand research methods used in the empirical educational sciences  
|              | - Understand and critically examine information from scientific journals and media  
|              | - Understand pedagogically relevant findings from the empirical educational sciences |

### Subject Didactics in Sport

Important: You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
</table>
| 557-0315-00L | Sports Didactics I †  
|              | Only for Teaching Diploma Sports.  
|              | Simultaneous enrolment in Introductory Internship Sports - course 557-0210-00L - is compulsory. |
| Abstract     | Practical implementation in sports of general didactics, with the planning, implementation and evaluation of topics from all the sports-specific areas of tuition in secondary school Level II. |

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Objective: The students:
- Implement the objectives of general didactics in respect of the different types of sport at school.
- master the planning, implementation and evaluation of topics from all the sports-specific areas of tuition.
- gain an overview of the necessary for the different requirements placed on a sports teacher at secondary school Level II.
- try out different teaching structures, such as the lesson, teaching unit, block periods and extra units in sport in addition to those on the timetable.

Content: Implementation of practical sport into general teacher training with planning, execution and evaluation of the topics from all sport-specific areas of the education at this level in Section II.

Lecture notes: See moodle 00 - Lehrdiplom Sport

Literature:
- Röthig P.: Sportwissenschaftliches Lexikon, Schorndorf Verlag 2003

### Professional Training in Sport

**Notice:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>557-0210-00L</td>
<td>Introductory Internship Sports</td>
<td>O</td>
<td>3</td>
<td>6P</td>
<td>O. Graf, R. Scharpf</td>
</tr>
<tr>
<td>557-0208-00L</td>
<td>Teaching Internship Sport</td>
<td>O</td>
<td>8</td>
<td>17P</td>
<td>O. Graf, R. Scharpf</td>
</tr>
</tbody>
</table>

**Notice:** Only for Teaching Diploma Sports.

- Simultaneous enrolment in Sports Didactics I - course 557-0315-00L - is compulsory.
- During the introductory teaching practice, the students sit in on 3 lessons given by the teacher responsible for their teaching practice, and teach 7 lessons themselves. The students are given observation and reflection assignments by the teacher responsible for their teaching practice.
- Right at the start of their training, students acquire initial experience with the observation of teaching, the establishment of concepts for teaching and the implementation of teaching. This early confrontation with the complexity of everything that teaching involves helps students decide whether they wish to and, indeed, ought to, continue with the training. It forms a basis for the subsequent pedagogical and subject-didactics training.
- Students observe 3 and teach 7 lessons, supervised by experienced teachers.

**Lecture notes:** See moodle 00 - Lehrdiplom Sport
Die Studierenden erfahren das Lektionsthema in der Regel eine Woche vor dem Prüfungstermin. Von der zuständigen Lehrperson erhalten

Students use their disciplinary skills and educational knowledge for teaching.

Examination Lesson I Sports

On the basis of a specified topic, the candidate shows that they are in a position

- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle

- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Simultaneous enrolment in “Examination Lesson II Sports” (557-0211-02L) is compulsory.

Simultaneous enrolment in “Examination Lesson I Sports” (557-0211-01L) is compulsory.

Examination Lesson II Sports

- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Simultaneous enrolment in “Examination Lesson II Sports” (557-0211-02L) is compulsory.

Simultaneous enrolment in “Examination Lesson I Sports” (557-0211-01L) is compulsory.

Examination Lesson I Sports

On the basis of a specified topic, the candidate shows that they are in a position

- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle

- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Simultaneous enrolment in “Examination Lesson II Sports” (557-0211-02L) is compulsory.

Simultaneous enrolment in “Examination Lesson I Sports” (557-0211-01L) is compulsory.

Examination Lesson II Sports

On the basis of a specified topic, the candidate shows that they are in a position

- to develop and conduct teaching that is conducive to learning at high school level, substantiating it in terms of the subject-matter and from the didactic angle

- to analyze the tuition they have given with regard to its strengths and weaknesses, and outline improvements.

Simultaneous enrolment in “Examination Lesson II Sports” (557-0211-02L) is compulsory.

Simultaneous enrolment in “Examination Lesson I Sports” (557-0211-01L) is compulsory.

Examination Lesson I Sports

### Specialized Courses in Respective Subject with Educational Focus I

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>376-1033-00L</td>
<td>History of Sports</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Gisler</td>
</tr>
</tbody>
</table>

**Abstract**
Comprehension for development and changes of sports from the ancient world to the present. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

**Objective**
Understanding for the development and adaptation of sports from the ancient world to present times.

**Content**

**Lecture notes**
Ein Skript für die aktuelle Veranstaltung wird abgegeben.

**Literature**

| 376-1107-00L   | Sport Pedagogy                  | W    | 2    | 2V    | C. Herrmann     |

**Abstract**
The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on "pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education".

**Objective**
Development of pedagogical-psychological competences for the optimisation of future teaching activities.

**Content**
- Subject area of educational psychology
- Motivating students in physical education
- Building self-efficacy and strengthen the self-concept
- Promoting positive emotions and a positive attitude to anxiety
- Encouraging self-directed learning
- Leading classes and promoting cooperation
- Communicating with students efficiently
- Reflecting your own expectations critically
- Handling gender issues sensitively
- Promoting inclusion / Strengthening social and moral development
- Dealing with difficult students
- Evaluating achievements of students

**Lecture notes**
Teaching materials for the individual lectures are provided to the students via moodle.

**Literature**
Primärliteratur:

| 376-1117-00L   | Sport Psychology                | W    | 2    | 2V    | H. Gubelmann    |

**Abstract**
This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

**Objective**
Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

**Content**
- Main Topics
  - Introduction to sport psychology
  - Cognitions in sports: mental rehearsal and mental training
  - Emotions and stress
  - Motivation: goal-setting in sports
  - Career and career transition in elite sport
  - Coach-Athlete-Interaction
  - Psychological aspects of sport-injury rehabilitation
  - Group dynamics in sport

**Lecture notes**
Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

**Literature**


| 376-1127-00L   | Sociology of Sport              | W    | 2    | 2V    | R. Bürgi, M. Lamprecht |

**Abstract**
These lectures deal with the current changes of sports from the ancient world to present times. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

**Objective**
The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes and becomes more differentiated in the process
- take current examples to highlight the sociological view of sport.

**Content**
Sport and social change: developments and trends
- The economy and the media: dependencies, consequences, scandals
- Social inequalities and distinctions: gender differences and group behavior
- Conflicts and politics: sports organizations, doping, violence

**Lecture notes**
Selected materials for the lecture are available on the Moodle platform.

**Literature**

A detailed program with additional references will be delivered at the beginning of the lecture.
### Mentored Work Specialised Courses in the Respective Subject with an Educational Focus Sport A

**Only for Teaching Diploma Sports.**

**Abstract**

Pedagogical application of research projects for schools. Introduction of sports pedagogical oriented research projects. Competency to a youth friendly movement and sports education. Competent "pedagogical application" of research projects in the field of movement and sport. Feed in of scientific findings to school lesson settings.

**Objective**

- The students combine and apply general educational aims with a general and specific background of research projects.
- They know different educational concepts of the above mentioned, recognise its strengths and weaknesses and are able to apply concepts appropriate to the situation.
- They are interested in the (thought-) processes of education and research in sports in Switzerland.
- They use their knowledge of research matters to guide educational thought-processes.
- They are interested in processes of research in sport.
- They approach the research interest of their pupils with the knowledge of sports psychology, sports sociology, sports pedagogy, and sports history.

**Content**

- Die Studierenden wenden die Bewegungs- und Lernziele des Sportunterrichts aus den kantonalen Lehrplänen im Unterricht an und können diese begründen.
- Sie interessieren sich für die Prozesse der Forschung im Sport.
- Sie erlernen anhand von Projektarbeiten die didaktische Anwendung der Sportpsychologie, Sportsoziologie, Sportpädagogik und Sportgeschichte und ziehen daraus Konsequenzen für den situativ-variabel orientierten Unterricht.
- Sie setzen ihr Wissenschaftswissen ein, um bei den Lernenden Denkprozessen anzustoßen und zu begleiten.

**Lecture notes**

Skript unter: https://moodle-app2.let.ethz.ch/course/view.php?id=117

**Literature**

Literaturverweise erfolgen jeweils in den gewählten Fachbereichen

**Prerequisites / notice**

Auswahl von 2 aus 4 Angeboten:
- Motor-Learning im Sport (Fachbereich Sportpsychologie)
  - Vorlesung
  - Praktische Umsetzung von Forschungsprojekten für die Schule
- Sport im Spannungsfeld zwischen Ethik und Kommerz (Fachbereich Sportsoziologie)
  - Vorlesung
  - Praktische Umsetzung von Forschungsprojekten für die Schule
- Mehrperspektivität im Sportunterricht (Fachbereich Sportpädagogik)
  - Vorlesung
  - Praktische Umsetzung von Forschungsprojekten für die Schule
- Historische Entwicklung der Lehr und Lernmodelle im Sportunterricht (Fachbereich Sportgeschichte)
  - Vorlesung
  - Praktische Umsetzung von Forschungsprojekten für die Schule
  - Alle Wahlfachangebote beinhalten:
  - Sportwissenschaftliche Fachpraxis
  - Praktische Umsetzung der Erkenntnisse für die Schule

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#### Specialized Courses in Respective Subject with Educational Focus II

At least 6 CP's must be obtained in this category.

Further courses must be chosen from the "Sport Practical: Major Education".

### Compulsory Elective Courses

At least 6 CP's must be acquired in this category.

Further courses must be chosen from the "Sports Practice: Major Education and Specialized Education".

### Sports Practice

The Teaching Diploma in Sports will only be granted to students holding a Master, Diploma or Licentiate degree in Human Movement Sciences and Sports or Health Sciences and Technology. Additionally, a Sports Practice encompassing 56 CP's is required. The Sports Practice can be partly conducted during the Bachelor and Master programmes in Sports.

### Assessments

#### Assessment I Shaping

*Only for Health Sciences and Technology BSc and Teaching Diploma Sports.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>557-0101-00L</td>
<td>Assessment I Shaping</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>M.-M. Jäggi, C. König</td>
</tr>
</tbody>
</table>
The students should be able to:
- acquire and consolidate apparatus related core movements as well as apply and create such combinations
- utilize their own strength as well as the resulting impact in a differentiate way in order to precisely move the swinging, flying, falling and twisting body
- gain orientation safety and equilibrium while twisting and flying
- Rhythmised attainment of specific acrobatic requirements with music
- - Change of positions on the trampoline respecting coordinative aspects
- Accomplishment of an Indoor Parkour

Assessment II 'achievement' allows students to continue their studies in the basic subjects of athletics, fitness, swimming and trend sports. Aim is to acquire the basic skills for the respective sports discipline.

Abstract
The assessment monitors both the physical fitness of the students and their skills in the fields of athletics and fitness, which forms the basis for a successful rounding off of the respective direction of study.

Objective
The assessment II 'achievement' allows students to continue their studies in the basic subjects of athletics, fitness, swimming and trend sports. Aim is to acquire the basic skills for the respective sports discipline.

Content
- To understand music and to be able to interpret the music's character
- To improve coordination with the help of music
- To expand the diversity and repertoire of movements
- To gain insight into different dance styles
- To improve one's own dance technique in framework of the topics offered: To acquire and expand personal skills and knowledge
- To gain insight into different dance styles
- To improve one's own dance technique in framework of the topics offered: To acquire and expand personal skills and knowledge

Prerequisites / notice
Kenntnisse (Schulniveau) in den Sportfächern Fitness und Leichtathletik werden ebenso vorausgesetzt wie angemessene konditionelle Fähigkeiten.

### Basic Education

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>557-0103-00L</td>
<td>Assessment II Toning</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>M. Zürcher, A. Krebs, M. Perk</td>
</tr>
</tbody>
</table>

**Abstract**

Only for Health Sciences and Technology BSc and Teaching Diploma Sport.

**Objective**

The assessment II 'achievement' allows students to continue their studies in the basic subjects of athletics, fitness, swimming and trend sports. Aim is to acquire the basic skills for the respective sports discipline.

**Content**

- To gain orientation safety and room orientation while twisting and flying
- to observe, to advise) within a small group.

### 557-0412-01L Dance I

**Abstract**

Dance and movement comprise of expression, strength, endurance, suppleness, flexibility, rhythmic movement sequences, coordination and dance cuts with music - combined with creativity. Implementation of these aspects.

**Objective**

- To enjoy dancing without prior knowledge and to experience the possibilities within dance from easy to hard
- To gain insight into different dance styles
- To improve personal skills and knowledge on the floor and in acrobatics as well as to create individual and cooperative combinations according to qualitative criteria.

**Content**

- To enjoy dancing without prior knowledge and to experience the possibilities within dance from easy to hard
- To improve personal skills and knowledge on the floor and in acrobatics as well as to create individual and cooperative combinations according to qualitative criteria.

### 557-0433-00L Apparatus Gymnastics and Trampoline I

**Abstract**

To get to know and understand the basics of movement (core movements) and its respective actions and functions on apparatuses, on the floor and in acrobatics as well as to create individual and cooperative combinations according to qualitative criteria.

**Objective**

The students should be able to:
- - core poses as motor basic training
- - structural relationships within rotations (turnarounds, handsprings and free somersaults)
- - structural relationships within rotations (turnarounds, handsprings and free somersaults)
- - move and change position on the trampoline respecting coordinative aspects
- - core poses as motor basic training
- - structural relationships within rotations (turnarounds, handsprings and free somersaults)
- - different forms of vaulting as well as springing in movements like handstands and somersaults
- - To understand music and to be able to interpret the music's character
- - To improve coordination with the help of music
- - To gain insight into different dance styles
- - To improve one's own dance technique in framework of the topics offered: To acquire and expand personal skills and knowledge

**Content**

- Der Tanz und die Bewegung beinhalten Ausdruck, Kraft, Ausdauer, Geschmeidigkeit, Flexibilität, rhythmische Bewegungsabläufe, Koordination und Tanzphrasen mit Musik- gepaart mit Kreativität und Lebensfreude
- - core poses as motor basic training
- - structural relationships within rotations (turnarounds, handsprings and free somersaults)
- - gain orientation safety and room orientation while twisting and flying
- - To understand music and to be able to interpret the music's character
- - To improve coordination with the help of music
- - To gain insight into different dance styles
- - To improve one's own dance technique in framework of the topics offered: To acquire and expand personal skills and knowledge

### 557-0454-01L Swimming I

**Abstract**

Basic education in swimming: swimming, diving, water polo and artistic swimming
**Objective**

All kind of swimming:
- learns to know and understand the individual basic techniques
- improvement of technical skills and crafts

**Content**

- Schwimmen: Erwerben und festigen der Schwimmtechniken Rücken, Brust und Kraul sowie Grundform Delfin. Erwerben und Festigen
- Start und Wenden Kraul und Brust.
- Wasserpringen: Erwerben und festigen Grundtechniken Eintauchen und Absprungen aus verschiedenen Ausgangspositionen und
  Abspunghöhen. Einzelne Kernsprünge.
- Artistic Swimming: Erwerben und festigen Wassertreten, Paddeln, einzelne Grundfiguren.

**Lecture notes**

Wird abgegeben

**Literature**

- Swimsports.ch: Schweizerische Tests im Schwimmsport

**Prerequisites / notice**

Assessment II BSc HST erfolgreich abgeschlossen.

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**557-0503-01L Basketball 1**

*Prerequisites:* Assessment III (BSc HST).

**Abstract**

Basketball-Basics:
- Basic technical skills: dribbling/ballhandling, passing, shooting, footwork and defense related to the specific Basketball rules.
- Tactical skills: 1 on 1, give & go, hand-off, pick & roll, pick & pop and the application of these skills in a game 3 on 3 on one basket.

**Objective**

The students know the technical basic Basketball elements (dribbling, changes of hand, stops, starts, footwork, pass, shot, defense), they can demonstrate them and use them correctly in a game situation 3 on 3 on one basket. The students know the tactical Basketball elements (1 on 1, give & go, hand-off, pick & roll, pick & pop) and can apply these skills in a game 3 on 3 on one basket.

**Content**

Learning the basic elements in drills and games, learning (pre-)tactical elements (1-1, getting open, 2-2, backdoor cut, frontdoor cut, 3-3, give & go, hand-off, pick & roll, pick & pop, spacing) and assemble them into systems, that can be used in a game 3 on 3 on one basket.

**Lecture notes**

available on Moodle

**Literature**

- manual for monitors of the Swiss Youth & Sports program (available through the "Jugend & Sport" office, german / french / italian)

Cherret, Michel: Basketball. Fundamental skills for offensive play. Video (german / french). Magglingen, BASPO, 2003 (CHF 34.-). Order at video@baspo.admin.ch

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**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
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<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
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<td>Analytical Competencies</td>
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<td></td>
<td>Decision-making</td>
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<tr>
<td></td>
<td>Media and Digital Technologies</td>
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<td></td>
<td>Problem-solving</td>
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<td>Project Management</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Self-presentation and Social Influence</td>
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<td>Domain D - Personal Competencies</td>
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<td>Self-awareness and Self-reflection</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
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</tr>
</tbody>
</table>

**557-0514-03L Soccer I**

*Prerequisites:* Assessment III BSc HST.

**Abstract**

Acquisition/consolidation basic skills for soccer.

Support and development the individual conditions/talent/skill and introduction of basic methods will be treated.

**Objective**

Support and development the individual conditions/talent/skill and introduction of basic methods want to be at the centre of attention.

**Content**

Technique:
- Dribble, short passport play, get the ball under control, shot,

**Literature**

- Bucher, Walter (Hrsg.) 1020 Spiel- und Übungsformen im Kinderfußball, 7. unveränderte Auflage 2011, Hofmann-Verlag, Schorndorf

**Prerequisites / notice**

1. Prerequisites:
- Small being able in soccer.
- Readiness to train.

2. After this course you can get the licence "manager for children".

Prerequisites: Only 1 absence from the lessons "football for children", the book "Kinderfußball" can be bought in the course
Floorball I 2 credits W 2G F. Ungrad

Prerequisites: Assessment III BSc HST

Abstract
Experiencing Unihockey/Floorball as an indoor sportsgame
Learning by doing to improve personal sport skills and widening personal abilities in ball sports
Learning by practising/playing and linking that knowledge to theories of motor learning

Objective
Practising unihockey to improve personal sport skills and widening personal abilities in ball sports
Improvement of personal unihockey-skills
Learning by practising/playing and linking that knowledge with theories of motor learning

Content
Transfer of ideas into motor movements and motor skills
Personal improvement by practising different motor skills as moving the ball/ballcontrol, passing, shooting
Training of personal sports abilities in ballgames
Analysis of play-situations and corresponding motor movement
Understanding, learning and applying the rules of the game

Prerequisites / notice
Please bring your personal hockey stick with you to class.

Handball I 2 credits W 2G F. Lüchinger

Prerequisites: Assessment III (BSc HST).

Abstract
Learn by playing - from three-a-side to four-a-side games.
Game development takes place over the zone play of the game (2/1) or 3/2 to the game 4/4 or (6/6).

Objective
The students improve their personal skills and demonstrate the game in teams as well as groups of 4 against 4.
They deepen the development of the game
They improve their personal skills with an individual emphasis on game and practice.

Content
Spielend Handball lernen - Über das Spiel zum Spiel (Vom Spiel 3/3 zum Spiel 4/4)
Die Spielentwicklung erfolgt über die Zonenspiele vom Spiel 2/1 oder 3/2 bis zum Spiel 4/4 oder (6/4/6).
Die eingeführten technischen Elemente bilden die Voraussetzung für die vorwiegend taktisch ausgerichteten Zonenspiele und werden ausschließlich in der Anwendungs- und Gestaltungsstufe trainiert.
Techniktraining ist Sache der Studierenden.
Die individuelle Grundschulung wird mit Lernkontrollen überprüft (Kontrollblätter).
Alle ausgewählten Formen müssen als Lernkontrolle durchführbar sein.

Prerequisites / notice
Testübungsbemängelungen (3 entscheidungswürdige) und 3 unentscheidungswürdige Absenzen)
Testübungsbemängelungen:
Im Rahmen der Ausbildung werden Zonenspiele und Fertigkeiten erarbeitet. Für das Testat (Bewegungswissenschaft ler) müssen insgesamt 5 Testübungsbemängelungen aus min. 4 praktischen Bereichen abgegeben werden.

Prüfungen: Freiwillig
Inhalte: Die Prüfungsinhalte werden während des Semesters erarbeitet und am Ende des Semesters schriftlich abgegeben.

Badminton I 2 credits W 2G

Prerequisites: Assessment III (BSc HST).

Abstract
Does not take place this semester.

Objective
To learn and to deepen technical and tactical abilities and skills of the game:
to show methodical learning- and structural series
to learn the basic strokes
to learn the basic foot work
to get to know single and double tactics
to try out different game variations

Lecture notes
Lehrunterlagen können von der Homepage abgerufen werden.

Literature
L. Ochsenbein/ O. Buholzer

Pre requisites / notice
Testübungsbemängelungen
Präsenz:
Maximale Abwesenheiten (3 entscheidungwürdige, 3 unentscheidungwürdige Absenzen)

Prüfungen: Freiwillig
Inhalte: Die Prüfungsinhalte werden während des Semesters erarbeitet und am Ende des Semesters schriftlich abgegeben.

Snowsports I - Ski 2 credits W 2G C. Elmiger-Schnyder, further lecturers

Prerequisites: Assessment I+II (BSc HST) passed.

Abstract
Education in the disciplines of winter sports.
- J+S Education possibility
- Transfer Offpist
- Transfer Nordic Cross

Objective
The students:
- experience the different winter sports.
- gain an understanding of how to ski off-piste.
- Transfer: Input Nordic Cross!

Content
- To apply and vary personal technique of alpine skiing
- To acquire and vary personal technique of cross-country skiing
- Competition in ski-jumping, and giant slalom
- To gain an understanding in how to ski off-piste
- To gain Nordic Cross

Prerequisites / notice
Requirement: Assessment I + II (BSc HST)
557-0603-02L  Snowsports I - Snowboard  
**Prerequisites:** Assessment I+II (BSc HST) passed.

**Abstract**
Education in the disciplines of winter sports.
- J+S Education possibility
- Transfer Offpist
- Transfer Nordic Cross

**Objective**
The students:
- Experience the different winter sports!
- Gain an understanding of how to ski off-piste!
- Gain an understanding of how to Nordic Cross.

**Content**
- To apply and vary personal technique of snowboarding
- To acquire and vary personal technique of cross-country skiing
  - Competition in ski-jumping, and giant slalom
- To gain an understanding in how to ski off-piste
- To gain an understanding in how to Nordic Cross

**Prerequisites / notice**
Requirement: Assessment I + II (BSc HST)

#### Major Education

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
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<tbody>
<tr>
<td>557-0426-00L</td>
<td>Fitness II</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>A. Sonderegger, C. Romano</td>
</tr>
</tbody>
</table>

**Abstract**
Acquisition of further skills and deepened knowledge in the areas of fitness coaching and group fitness.

**Objective**
- Anamnese und Trainingsplanung
- Trainingsmittel im Fitnessbereich
- Methoden im Kraft- und Ausdauerbereich
- Einführung von Personen an Fitnessgeräten, Instruktion und Korrektur
- Funktionelle Anatomiekennnisse im Fitnessbereich
- Sicherheits- und Trainingsregeln im Group Fitness
- verbales & visuelles Cueing
- Funktionelles Training im Group Fitness
- Training der Tiefenmuskulatur ohne/mit instabiler Unterlage
- Koordinationtraining ohne/mit Hilfsmittel
- Sicherheits- und Trainingsregeln im Group Fitness

**Content**
- Anamnese und Trainingsplanung
- Trainingsmittel im Fitnessbereich
- Methoden im Kraft- und Ausdauerbereich
- Einführung von Personen an Fitnessgeräten, Instruktion und Korrektur
- Funktionelle Anatomiekennnisse im Fitnessbereich
- Sicherheits- und Trainingsregeln im Group Fitness
- verbales & visuelles Cueing
- Funktionelles Training im Group Fitness
- Training der Tiefenmuskulatur ohne/mit instabiler Unterlage
- Koordinationtraining ohne/mit Hilfsmittel
- Sicherheits- und Trainingsregeln im Group Fitness

**Prerequisites / notice**
- Skript und Unterlagen Fitness I
- Training fundiert erklärt, J. Hegner, 5. Auflage 2012

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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<td>Badminton / Volleyball II</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>M. Attinger, P. Lüscher Luchsinger</td>
</tr>
</tbody>
</table>

**Abstract**
Acquirement and Application of classic as well as modern forms of movement on different apparatuses and on the trampoline

**Objective**
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

The students should be able to:
- enhance their repertoire on apparatus specific movements
- deepen their existing store of movements
- improve their individual performance competencies
- realize and comprehend transfer characteristics within the movement learning process
- work up methodically and didactically a chosen skill
- gain sensitivity for social competences (e.g. to assist, to observe, to advise) within a small group
- compose and present to music within a group of three a creative performance

**Content**
- further core movements und its combinations on different apparatuses
- handsprings and (free) somersaults back- and forwards, respectively twists back- and forwards on different apparatuses
- creative and cooperative composition in a threesome accompanied by music
- vault springs and touching down springs (stuetz springs) to overcome obstacles in an artful way (Freerunning)
- integrated theoretical coherences of the qualitative movement learning process
- conveyance of methodical and didactical principles as well as topic specific criteria
- functional warm-up with regard to specific contents

**Prerequisites / notice**
Voraussetzungen:
- abgeschlossene (nicht zwingend bestandene) Grundausbildung in
- Akrobatik
- Geräteturnen/Trampolin

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<td>M. Attinger, P. Lüscher Luchsinger</td>
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</tbody>
</table>

**Abstract**
- Apparatus Gymnastics and Trampoline I (557-0433-00L)

**Objective**
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

The students should be able to:
- enhance their repertoire on apparatus specific movements
- deepen their existing store of movements
- improve their individual performance competencies
- realize and comprehend transfer characteristics within the movement learning process
- work up methodically and didactically a chosen skill
- gain sensitivity for social competences (e.g. to assist, to observe, to advise) within a small group
- compose and present to music within a group of three a creative performance

**Content**
- further core movements and its combinations on different apparatuses
- handsprings and (free) somersaults back- and forwards, respectively twists back- and forwards on different apparatuses
- creative and cooperative composition in a threesome accompanied by music
- vault springs and touching down springs (stuetz springs) to overcome obstacles in an artful way (Freerunning)
- integrated theoretical coherences of the qualitative movement learning process
- conveyance of methodical and didactical principles as well as topic specific criteria
- functional warm-up with regard to specific contents

**Prerequisites / notice**
- abgeschlossene (nicht zwingend bestandene) Grundausbildung in
- Akrobatik
- Geräteturnen/Trampolin

**Literature**
- Skript und Unterlagen Fitness I
- Training fundiert erklärt, J. Hegner, 5. Auflage 2012

**Lecture notes**
Wird im Unterricht abgegeben oder auf Moodle bereitgestellt
Abstract
Badminton:
In this course you will build up and experience different tactical and technical exercise forms for classes. At the same time you will be able to deepen your own skills.

Volleyball:
Identify and experience the main aspects of teaching volleyball and adapt it for your own lessons using didactical and methodical concepts.

Improve individual technical and tactical skills in volleyball.

Objective
The level II courses focus on methodological concepts and didactics. The goal is to learn how to teach the specific sport at high school level. The didactical aspects are often conveyed through new skills and elements. It is not required to have passed the level I course, but it is mandatory to have attended it previously.

Badminton:
To build methodical and didactical concepts to teach badminton classes.
To deepen your own technical and tactical abilities.

Volleyball:
You identify and experience the main aspects of teaching volleyball and adapt it for your own lessons using didactical and methodical concepts.
You improve your individual technical and tactical skills in volleyball.

Content
Badminton:
In this course we work on possibilities to build up different tactical and technical exercise forms and structures for classes. You get to know a variety of games. You learn how you can diversify exercises – depending on the level and the age of your pupils.

Volleyball:
You experience and discuss the main problems of teaching volleyball in school. You learn in practice how to deal with it and work out your own solutions.
You improve your individual technical and tactical skills in diverse games and practice drills.

Lecture notes
Published during the semester on "moodle".

Prerequisites / notice
Prerequisite: Basic course completed

Education Acquired Outside ETH

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>557-0450-00L</td>
<td>Life Saving Rescue Test Plus Pool SLRG</td>
<td>O</td>
<td>2 credits</td>
<td>external organisers</td>
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<td></td>
<td>Only for Teaching Diploma Sports.</td>
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<tr>
<td></td>
<td>Confirmation of course attendance Brevet Basis Pool and Brevet Plus Pool SLRG.</td>
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<tr>
<td></td>
<td>External education! Credit points only for Teaching Diploma Sports!</td>
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<tr>
<td>Abstract</td>
<td>Acquisition of “SLRG Brevet Plus Pool”.</td>
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<tr>
<td>Objective</td>
<td>Based on the Brevet Basic Pool, the Brevet Plus Pool provides you with skills to supervise groups in unguarded pools.</td>
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<td></td>
<td>To recognize danger in, on and around water</td>
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<td></td>
<td>Knowledge and handling of life saving equipment</td>
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<td></td>
<td>Rescue and towing techniques</td>
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<td>Orientation under water</td>
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<tr>
<td></td>
<td>To rescue a person</td>
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<tr>
<td></td>
<td>Basis knowledge in anatomy and first aid</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: please consult <a href="http://www.srlg.ch">www.srlg.ch</a></td>
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</table>

| 557-0451-00L | First Responder Level 2 | O    | 2 credits | external organisers |
|              | Only for Teaching Diploma Sports. |      |       |       |                               |
|              | Confirmation of course attendance "First Responder Level 2 IVR" |      |       |       |                               |
|              | More information: www.samariter.ch or ivr-ias.ch |      |       |       |                               |
| Abstract    | Acquisition of the certificate "Ersthelfer Stufe II IVR". |      |       |       |                               |
| Objective   | In this course you will acquire the basic knowledge related to safety and hygiene measures in case of injuries and acute illnesses. |      |       |       |                               |
|            | - To be able to judge an injured person and to apply life saving actions |      |       |       |                               |
|            | - To carry out wound treatment with actual bandage |      |       |       |                               |
|            | - To list the characteristics of a sprain, strain, dislocation and to apply first-aid interventions |      |       |       |                               |
|            | - To carry out fixed bandages with common material |      |       |       |                               |
|            | - To explain the function of the cardiovascular system |      |       |       |                               |
|            | - To name the symptoms of poisoning |      |       |       |                               |
|            | - To list the signs of acute illness |      |       |       |                               |
|            | - To put together the content of a first-aid box |      |       |       |                               |
|            | - To carry out safety interventions in daily situations. |      |       |       |                               |
| Content    | * Hautverletzungen |      |       |       |                               |
|            | * Wundinfektion / Blutvergiftung |      |       |       |                               |
|            | * Stürze im Alltag (Verstauchungen, Prellungen, Quetschungen) |      |       |       |                               |
|            | * Sportverletzungen, Knochenbrüche |      |       |       |                               |
|            | * Herzkreislaufstörungen |      |       |       |                               |
|            | * Alltagserkrankungen in der Familie |      |       |       |                               |
| Prerequisites / notice | Prerequisites: please consult www.samariter.ch |      |       |       |                               |

| 557-0452-00L | J+S-Coach School and Youth Sports | O    | 2 credits | external organisers |
|              | Only for Teaching Diploma Sports. |      |       |       |                               |
|              | Acquisition of the certificate "J+S-Coach School and Youth Sports" |      |       |       |                               |
Youth Sports.

External education! Credit points only for Teaching Diploma Sports.
Information on signing in for the course will be provided by the study administration HST.

Abstract
Acquisition of the Certificate "J+S-Coach School and Youth Sports" in the course of "Magglinger Hochschulwochen".

Objective
- to experience and reflect on qualitatively good sports using practical examples.
- to get to know the institution BASPO/EHSM with its tasks and network.
- to get to know the J+S program.
- to gain proficiency as a J+S Coach in school and youth sports.

★★ Compensation Courses★★

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>557-0603-01L</td>
<td>Snowsports I - Ski</td>
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<tr>
<td></td>
<td>Prerequisites: Assessment I+II (BSc HST) passed.</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>C. Elmiger-Schnyder, further lecturers</td>
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<tr>
<td>Abstract</td>
<td>Education in the disciplines of winter sports.</td>
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<tr>
<td></td>
<td>- J+S Education possibility</td>
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<td></td>
<td>- Transfer Offpist</td>
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<td></td>
<td>- Transfer Nordic Cross</td>
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<tr>
<td>Objective</td>
<td>The students:</td>
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<tr>
<td></td>
<td>- experience the different winter sports.</td>
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<td></td>
<td>- gain an understanding of how to ski off-piste.</td>
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<td></td>
<td>- Transfer: Input Nordic Cross!</td>
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<tr>
<td>Content</td>
<td>- To apply and vary personal technique of alpine skiing</td>
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<td></td>
<td>- To acquire and vary personal technique of cross-country skiing</td>
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<td></td>
<td>Competition in ski-jumping, and giant slalom</td>
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<td>- To gain an understanding in how to ski off-piste</td>
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<td>- To gain Nordic Cross</td>
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<tr>
<td>557-0603-02L</td>
<td>Snowsports I - Snowboard</td>
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<td>Prerequisites: Assessment I+II (BSc HST) passed.</td>
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<tr>
<td>Objective</td>
<td>The students:</td>
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<tr>
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<td>- experience the different winter sports.</td>
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<td></td>
<td>- Gain an understanding of how to ski off-piste!</td>
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<tr>
<td></td>
<td>- Gain an understanding of how to Nordic Cross.</td>
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<tr>
<td>Content</td>
<td>- To apply and vary personal technique of snowboarding</td>
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<tr>
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<td>- To acquire and vary personal technique of cross-country skiing</td>
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<td>557-0605-01L</td>
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<tr>
<td>Prerequisite</td>
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<td>W</td>
<td>2 credits</td>
<td>2G</td>
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<tr>
<td>Abstract</td>
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<td></td>
<td>Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports.</td>
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<tr>
<td>Objective</td>
<td>Snow sports Skiing:</td>
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<tr>
<td></td>
<td>- To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport.</td>
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<tr>
<td>Content</td>
<td>Snow sports Skiing:</td>
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<td></td>
<td>- General and specific education of personal competency in technique of the chosen snow sport.</td>
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<td>Requirement: Basic course in Snowsport I completed.</td>
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<tr>
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<tr>
<td>Objective</td>
<td>Snow sports (Snowboarding):</td>
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<tr>
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<td>- To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport.</td>
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<tr>
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<td>Snow sports (snowboarding):</td>
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<tr>
<td></td>
<td>- General and specific education of personal competency in technique of the chosen snow sport: Park, Piste and Off-Piste</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Requirement: Basic course in Snowsport I completed.</td>
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<tr>
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<td>Snowsports II - Telemark</td>
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<tr>
<td>Prerequisite</td>
<td>Basic course Snowsports I passed.</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>C. Elmiger-Schnyder, further lecturers</td>
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<tr>
<td>Abstract</td>
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<td>Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports.</td>
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</tbody>
</table>
Objective
Snow sports:
-To deepen and expand experience and skills in snow sports and in the personal competency of technique of the chosen snow sport.
-To expand skills to the area of telemark

Content
Snow sports:
-General and specific education of personal competency in technique of the chosen snow sport.
-Telemark as an extra experience in the framework of technique on slope, park and off-piste.

Prerequisites / notice
Requirement: Basic course in Snowsport I completed.

557-0605-04L Snowsports II - Off-piste 2
Prerequisite: Basic course Snowsports I passed.

W 2 credits 2G C. Elmiger-Schnyder, further lecturers

Only for students in Health Sciences and Technology and Teaching Diploma Sports.

Abstract
Specialization training: Acquisitions of special skills, getting to know the performance factors and training methods in the areas of Snowsports.

Objective
Off-piste education:
-Planning and realization of back-country skiing
-Handling of the environment
-Avalanche prophylaxis

Content
Off-piste education:
-Planning and realization of back-country skiing
-Handling of the environment
-Avalanche prophylaxis

Prerequisites / notice
Requirement: Basic course in Snowsport I completed.

Additional Requirements in Sports Science

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>376-0203-00L</td>
<td>Movement and Sport Biomechanics</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>B. Taylor, R. List</td>
</tr>
<tr>
<td>376-0207-00L</td>
<td>Exercise Physiology</td>
<td>W</td>
<td>4</td>
<td>3G</td>
<td>C. Spengler, F. Gabe Beltrami, R. M. Rossi</td>
</tr>
<tr>
<td>376-1033-00L</td>
<td>History of Sports</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>M. Gisler</td>
</tr>
<tr>
<td>376-1107-00L</td>
<td>Sport Pedagogy</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. Herrmann</td>
</tr>
</tbody>
</table>

Abstract
Comprehension for development and changes of sports from the ancient world to the presence. Description of sports in services of national idea, from education and health promotion from the middle of the 18th century till this day.

Objective
Understanding for the development and adaptation of sports from the ancient world to present times.

Content

Lecture notes
Ein Skript für die aktuelle Veranstaltung wird abgegeben.

Literature

Abstract
The teacher-student interaction presents a complex psychosocial event, demonstrating the need for a psychological extension of the classical social science / sports pedagogical perspective. Therefore, this lecture will be focused on "pedagogical-psychological aspects of competence development in the context of a multi-perspective physical education".

Objective
Development of pedagogical-psychological competences for the optimisation of future teaching activities.

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject. The lectures set out to:

- Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical exertion.

Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

**Content**

Main Topics

- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Objectives

- Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

Objectives

- Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

**Literature**


**Teaching materials for the individual lectures are provided to the students via moodle.**

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**376-1117-00L**

**Sport Psychology**

<table>
<thead>
<tr>
<th>W</th>
<th>2 credits</th>
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<tbody>
<tr>
<td>2V</td>
<td>H. Gubelmann</td>
</tr>
</tbody>
</table>

**Abstract**

This lecture is intended as an introduction to sport psychology and imparts knowledge on selected areas of the subject.

**Objective**

- Students are given insight into different work areas of sport psychology. In order to understand what «sport psychology» is, it is necessary to explain the essence and tasks of sport psychology and what it relates to, and to work out an underlying basis for key topics, such as cognition and emotions. Students' expertise is furthered by presenting and providing more in-depth treatment of additional topics of sport psychology. Selected intervention forms are intended to provide insight into applied sport psychology and ensure that mental processes and their impact in sport can be recognised. Case studies and practical exercises (e.g. objective training) are intended to prompt students to reflect to a greater extent on the forms in which sport psychology can be applied in their practice of sports and to integrate these in their teaching.

**Content**

- Main Topics
  - Introduction to sport psychology
  - Cognitions in sports: mental rehearsal and mental training
  - Emotions and stress
  - Motivation: goal-setting in sports
  - Career and career transition in elite sport
  - Coach-Athlete-Interaction
  - Psychological aspects of sport-injury rehabilitation
  - Group dynamics in sport

- These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

**Literature**


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**376-1127-00L**

**Sociology of Sport**

<table>
<thead>
<tr>
<th>W</th>
<th>2 credits</th>
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<tbody>
<tr>
<td>2V</td>
<td>R. Bürgi, M. Lamprecht</td>
</tr>
</tbody>
</table>

**Abstract**

These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

**Objective**

- The lectures set out to:
  - present the different dimensions, functions and interrelationships of present-day sport
  - provide an introduction to the central theories and models of (sport) sociology
  - show how far sport reflects society and how it changes and becomes more differentiated in the process
  - take current examples to highlight the sociological view of sport.

**Content**

- Sport and social change: developments and trends
- The economy and the media: dependencies, consequences, scandals
- Social inequalities and distinctions: gender differences and group behavior
- Conflicts and politics: sports organizations, doping, violence

**Literature**


**A detailed program with additional references will be delivered at the beginning of the lecture.**

**376-0130-00L**

**Laboratory Course in Exercise Physiology**

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
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<tr>
<td>4P</td>
<td>C. Spengler</td>
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</tbody>
</table>

**Abstract**

Conduct physical performance tests and measurements that are typically used to assess performance of athletes and/or patients and that deepen the understanding of physiological processes in response to physical exertion.

**Objective**

- Gain hands-on experience in exercise physiology and consolidate knowledge on physiological adaptations to different types and degrees of physical activity and climactic influences. Learn fundamental assessment techniques of the muscular system, the cardio-respiratory system and of whole-body performance, learn scientifically correct data analysis and interpretation of results. Insight into today's Sports Medicine.

**Content**

- Laboratory course: Various exercise tests assessing human performance and assessments of physiological responses to activity (examples are VO2max-test, Conconi-Tests, Determination of anaerobic threshold, Cooper-Test, 1-repetition maximum test, lactate minimum test), dynamometry, mechanography, body composition etc.). Insight into measurements in Sports Medicine.

**Literature**

- Schmidt/Lang/Heckmann: Physiologie des Menschen, Springer-Verlag, Heidelberg
- Kenney/Wilmore/Costill: Physiology of Sport and Exercise, Human Kinetics
Prerequisites / notice

Prerequisite:
Anatomy and physiology classes and lab course in physiology successfully completed (BWS students please contact C. M. Spengler)

Desirable:
Exercise Physiology Lecture (concomitantly or passed; is selection criterion in case of more applications than lab spaces)

376-2019-00L Applied Movement Analysis
W 2 credits 2G R. Scharpf, P. Schütz

Abstract
Based on examples from sports science, practical training and movement therapy, different methods of movement analysis are applied and compared.

Objective
Students are able to assess human movements using various methods of movement analysis. They learn to systematically analyse movements by structured observation and to apply scientific methods according to the situation.
They use modern technology as well as their own perception and experience.

Content
During the lecture students get acquainted with different scientific and practical methods of functional and biomechanical movement analysis.
Based on concrete examples, these methods will be applied and compared. The examples range from sport, everyday movement to therapy, such as ball sports, gymnastics/acrobatics, gait/running and strength training.
In the first phase of the lecture, the different approaches are presented and applied. In the process, current technical devices will be used.
In a second phase, individual projects are worked out in small teams. The projects will be discussed, presented and graded.

Lecture notes
Class material will be distributed using the moodle platform.

Sport Teaching Diploma - Key for Type

<table>
<thead>
<tr>
<th>O</th>
<th>Compulsory</th>
<th>Dr</th>
<th>Suitable for doctorate</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
<td>W</td>
<td>Eligible for credits</td>
</tr>
</tbody>
</table>

Key for Hours

<table>
<thead>
<tr>
<th>V</th>
<th>lecture</th>
<th>P</th>
<th>practical/laboratory course</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>lecture with exercise</td>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
<td>R</td>
<td>revision course / private study</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
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</table>

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
Public Policy Bachelor

1. Semester

Core Courses First Year Examinations

Examination Block 1

Students are free to take the exam either in German or in French. They may choose between 853-0723-00L 'Introduction to Torts, Contract and Insurance Law' or 851-0709-00L 'Introduction to Civil Law' (French)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0723-00L</td>
<td>Introduction to Torts, Contracts and Insurance Law</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>C. von Zedwitz</td>
</tr>
<tr>
<td>Abstract</td>
<td>Introduction to Torts, Contracts and Insurance Law.</td>
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<tr>
<td>Objective</td>
<td>The course shall make sure that the participants are fit to make the adequate decisions when encountering legal questions and issues in their career.</td>
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<tr>
<td>Content</td>
<td>In order to achieve this goal, legal problems and issues will be presented to the participants and then discussed in class.</td>
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</tr>
<tr>
<td>Prerequisites</td>
<td>The course 'Introduction au Droit civil' (851-0709-00) provides an introduction to the law of Contracts and Torts in French.</td>
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</tbody>
</table>

| 851-0709-00L | Introduction to Civil Law                  | W    | 2    | 2V    | H. Peter        |
| Abstract     | The course Private Law focuses on the Swiss Code of Obligations (contracts, torts) and on Property Law (ownership, mortgage and easements). In addition, the course will provide a short overview of Civil Procedure and Enforcement. |
| Objective    | Teaching of the principles of law, particularly private law. Introduction to law. |
| Content      | Le cours de droit porte notamment sur le droit des obligations (droit des contrats et responsabilité civile) et sur les droits réels (propriété, gages et servitudes). De plus, il est donné un bref aperçu du droit de la procédure et de l'exécution forcée. |
| Literature   | Editions officielles récentes des lois fédérales, en langue française (Code civil et Code des obligations) ou italienne (Codice civile e Codice delle obbligazioni), disponibles auprès de la plupart des librairies. |
| Prerequisites | Remarques |
| - Le cours de droit civil et le cours de droit public (2e sem.) sont l'équivalent des cours "Recht I" et "Recht II" en langue allemande et des exercices y relatifs. |
| - Les examens peuvent se faire en français ou en italien. |
| - Examen au 1er propédeutique; convient pour travail de semestre. |
| - Con riassunti in italiano. E possibile sostenere l'esame in italiano. |

| 851-0577-00L | Principles of Political Science            | O    | 4    | 2V+1U | T. Bernauer     |
| Abstract     | This course covers basic questions, concepts, theories, methods, and empirical findings of political science. |
| Objective    | This course covers basic questions, concepts, theories, methods, and empirical findings of political science. |
|             | Tipp: Lesen Sie zuerst genau die Übungsaufgaben für das zu studierende Buchkapitel (https://ib.ethz.ch/teaching/pwgrundlagen.html) und erst danach das betreffende Kapitel. Sie wissen dann beim Lesen schon vorweg, auf was Sie besonders genau schauen sollten. |
|             | Übungsaufgaben finden Sie hier: https://ib.ethz.ch/teaching/pwgrundlagen.html |
|             | Leistungskontrollen |
|             | a) Erster Test (12.11.2021, 14:15–15:00) |
|             | b) Zweiter Test (17.12.2021, 14:15–15:00) |
|             | Ergebnisse: gemittelt das Ergebnis der benoteten Semesterleistung |
|             | Ja nach Covid-19 Situation werden die beiden Tests entweder im Kursraum oder online durchgeführt (ausschliesslich eine der beiden Varianten, keine Wahlmöglichkeit). |
|             | Kreditpunkte | 4 ECTS-Punkte (Zeitaufwand insgesamt ca. 120 Arbeitsstunden) |
Understanding of basic microeconomic models. Ability to apply these models to real-world economic situations.

For the two-semester lecture series, the understanding of mankind in relation to working processes and its impact on organizations and the understanding of leadership theory in the past 100 years. They should grasp the concept of leadership responsibility (leadership ethics) and be able to derive consequences for leadership in practical situations. They should recognize the fundamental importance of communication in leadership situations and receive input that enables them to communicate adequately in specific situations.

At the end of this lecture course, students can:

(a) highlight the most important changes in the “long nineteenth century” in Europe
(b) assess the development of industrialization on the British Isles, urban growth in Switzerland, the difficult road to democracy in Germany, and French individualism.

Mandatory and further reading will be listed on the course plan that is made available as from the first session. Power Point Slides and references will be made available in digital form during the course of the semester.

Military Psychology and Pedagogy I
- Becoming acquainted with basic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences
- Knowing the possibilities and limitations of military education and deriving consequences

This lecture series does not build upon specific previous knowledge by the students.

History Part One: Europe (The Cradle of Modernity, Britain, 1789-1914)
A range of fundamental processes have transformed European societies in the course of the 19th and the 20th centuries. This lecture series asks whether one single model of modernization prevailed on the ‘Old Continent’ or whether we need to differentiate regionally. A special focus lies on the Swiss experience.

At the end of this lecture course, students can:
(a) highlight the most important changes in the “long nineteenth century” in Europe (b) explain their long-term effects; and (c) relate these changes to global developments today.

The thematic foci include: Industrialization on the British Isles, urban growth in Switzerland, the difficult road to democracy in Germany, and French individualism.

Power Point Slides and references will be made available in digital form during the course of the semester.

Mandatory and further reading will be listed on the course plan that is made available as from the first session.

This lecture series does not build upon specific previous knowledge by the students.

Military Psychology and Pedagogy I
- Becoming acquainted with basic psychological views of human behaviour and experience
- Knowing content- and process theories of motivation and being able to transfer them to the military context
- Knowing the possibilities and limitations of military education and deriving consequences
- Knowing the possibilities and limitations of military education and deriving consequences

This course is completed by a compulsory one week course between terms.

- Annen, H., Steiger, R. & Zwygart, U.: Gemeinsam zum Ziel, Huber, Frauenfeld 2004 (provided as pdf)
- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)

- Stadelmann, J.: Führung unter Belastung, Huber, Frauenfeld 1998 (provided as pdf)

This lecture is supported by a virtual learning environment containing relevant documents (presentations and texts) and information to further literature.

Teaching of formal requirements of scientific work (philosophy of science with a focus on the social sciences); literature reviews and the basics of conducting independent research on short as well as simple topics; basics of conceptualizing research designs for politically relevant questions and hypotheses.
Objective
1) Understanding the goal and the basic procedures of (empirical social sciences) scientific work (philosophy of science, theory building, research design, as well as the correct employment of sources, data and literature).
2) Identification of relevant research questions.
3) Creating a common basis for a thorough and systematic analysis of these.

Content
Political Methodology I seeks to introduce students to the basics of scientific work and procedures in the social sciences, which in turn shall allow them - also in conjunction with Political Methodology II - to conduct work that fulfills satisfactory standards of research quality throughout their further studies.

With regard to Political Methodology I, this seminar primarily focuses on the philosophy and theory of (empirical) social sciences, its structure, and procedures. The seminar emphasizes substantive contents and ways of presenting them, research and, conceptual work.

Additionally, it deals with the basis of establishing research designs with politically relevant questions and hypotheses.

Prerequisites / notice
Each student will be graded by two exercises (50% each).

1) Source analysis and acquisition: based upon a research question that will be given by the lecturer, the student shall collect a comprehensive list of the relevant literature and summarize that with her/his own words.

2) Critical analysis of sources: based upon a research article that the student chooses on her/his own, the student shall write a critical analysis of that, which mirrors frame and structure of scientific writing

Submission dates will be communicated in the first meeting.

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>853-0064-00L</td>
<td>Military Sociology I</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>T. Szvircev Tresch, S. de Rosa, T. Ferst</td>
</tr>
</tbody>
</table>

Abstract
Beside of the most important terms of sociology, demographic changes and the related value and structure change will be analysed. The second part focuses on organizational sociology. Thirdly, the course examines to which extent armed forces can be considered as organizations like any other and to which extent they constitute a special case from an organizational and normative point of view.

Objective
Recognize and explain current changes (social change) in modern society (individualisation, pluralisation); describe demographic changes in Switzerland; explain the structures of societies; define issues and fields of research in modern military sociology and explain the foundations of organisational sociology; explain the military in terms of organisational sociology and identify specific traits of the military as an organisation.

Content
Societal change; organizations as societal phenomena; aims, structures, environments of organizations; specifics of the military as an organization; impacts of technological and societal changes on the armed forces in modern societies.

Literature
A reader with a set of texts will be handed out.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Languages

First Foreign Language

Number      | Title                               | Type | ECTS | Hours | Lecturers |
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<tr>
<td>853-0405-00L</td>
<td>English, Part I</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Schweizer</td>
</tr>
</tbody>
</table>

Abstract
Teaching is focused on the acquisition of general English in the four classical skills, i.e. speaking, listening comprehension, reading comprehension and writing. The goal is to reach level B2 or C1 depending on the linguistic proficiency of the students.

Objective
This three-semester English course should enable the participants to successfully use the English language in an international military setting.

Content
Read, analyse and write military and civilian documents
Listening comprehension using current radio or TV reports
Practise speaking through group discussions and short presentations
Systematic revision and extension of key grammar points
Systematic acquisition of general and military vocabulary

3. Semester

Remaining Core Courses of the Bachelor Programme

Number      | Title                               | Type | ECTS | Hours | Lecturers |
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<tbody>
<tr>
<td>853-0015-00L</td>
<td>Conflict Research I: Political Violence</td>
<td>O</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. Juon</td>
</tr>
</tbody>
</table>
World Politics Since 1945: The History of International Relations

**Objective**
Knowledge on different types of political violence and their causes.

**Content**
This course offers an introduction to research on the causes and solutions to political violence in domestic and international politics. First, we discuss the definitions and concepts used in conflict research, the data and methods commonly applied and their historical development. Second, we focus on interstate wars and examine in this context state formation, nationalism and democracy. The third part of the course focuses on different types of political violence, including civil war, terrorism or social protests.

**Prerequisites / notice**
The course «Conflict Research II» in the following semester further examines civil wars.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>853-0047-00L</td>
<td>World Politics Since 1945: The History of International Relations Only for Public Policy BA and DAS Military Sciences</td>
<td>4 credits</td>
<td>2V+1U</td>
<td>A. Dossi, L. Horovitz</td>
</tr>
</tbody>
</table>

**Abstract**
This lecture series provides students with an overview of the development of international relations since the end of World War II. The first part of the series deals with the development of and changes in Cold War security policy structures. The second part deals with the period after the transformation of 1989/91; the focus here is on current issues in international security policy.

**Objective**
By the end of the semester, participants should have a solid knowledge of the history and theoretical foundations of International Relations since the end of the Second World War.

**Content**
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Reflection of common business practices.

**Prerequisites / notice**
The lecture is being supported by a website on Moodle. If you have any questions, please contact Oliver Roos (oliver.roos@sipo.gess.ethz.ch)

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<th>Code</th>
<th>Title</th>
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<th>Type</th>
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</thead>
<tbody>
<tr>
<td>853-0065-00L</td>
<td>Business Administration I Only for Public Policy BA</td>
<td>4 credits</td>
<td>3V</td>
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</table>

**Abstract**
The course BA I provides an understanding of the principles of General Business Management. It comprises an introduction to the basic business principles within a business acumen with a clear focus on value creation. The theory conveyed is illustrated with excercises, case studies and examples from business practice.

**Objective**
Objectives
- Understanding and application of instruments and methods of general management.
- Driving customer equity.
- Reflection of common business practices.

**Content**
I ENTERPRENEURIAL THINKING AND ACTION
- Customer orientation and value creation
- Business and Environment
- Legal forms of business under Swiss corporate law

II BUSINESS PROCESSES
- Marketing I
- Marketing II

III SUPPORTING PROCESSES
- Human Resource Management I
- Human Resource Management II

IV MANAGEMENT PROCESSES
- Organisation
- Value-based management
- Mission, Business Norms and Business Culture
- Strategic Management

**Literature**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0063-00L</td>
<td>Military History I Only for Public Policy BA</td>
<td>4 credits</td>
<td>2V+3U</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture outlines the development of the armed forces (assets regarding manpower, technology and armament), the concepts of warfare and the actual warfare in the 19th and 20th century.

**Objective**
- Distinguish between military history as a subject and historiography as a way of describing events;
- Analyse the modern developments regarding armed forces and warfare in the context of socio-economic changes;
- Based on the approach regarding revolution in military affairs, describe the evolution of the armed forces and of warfare;
- Exemplify the issues regarding the evolution of the combat (First and Second World War, Vietnam War and Algerian War).

**Content**
The lecture first examines the bases of the science of (military) history. It focuses on how military history developed from war history, on specific similarities and differences between military history and general historiography, the different ways of dealing with history in Switzerland, Germany, France and in the Anglo-Saxon cultural area (different approaches) as well as on institutions which deal with military history such as universities, military academies, national and international commissions and associations etc.

The lecture is structured along the lines of the concept of "Military Revolution" and starts with the formation of modern, European armed forces after the Oranian Army reform in the 17th century. Based on the "Military Revolution" approach, the lecture examines the structural changes regarding the armed forces and the development of warfare from the 18th to the 20th century. Special emphasis will be put on how the battlefield was revolutionized due to the Napoleonic wars, the industrialization in the 19th century, the First World War, the mechanization and totalization during the Second World War and the period of the Cold War.

**Literature**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>853-0082-00L</td>
<td>Strategic Studies I</td>
<td>3 credits</td>
<td>2V</td>
</tr>
</tbody>
</table>

**Abstract**
The lecture series treats high-impact strategic theory from antiquity to the present.
Objective

The participants know how the understanding of strategy has evolved over time. They understand the interplay of strategy’s basic components: ends, ways, means. They know the most important classics of strategy and war theory, especially against their specific historical background. Based on the analysis of historical and contemporary examples, they are aware of the mismatch between declaration and implementation of any given strategy. They are capable of analyzing original texts and modern scholarly works in the field of strategic studies.

Content

The two-term lecture series treats classic texts of strategic studies from antiquity to the present. Term 1 covers the theories up until roughly 1900, term 2 treats the theories eversince. Theories are considered classic if they were prominent in their respective times and if they enjoyed a strong reception thereafter, be it in literature, in academic debates or as guidelines for action (doctrine). Each out of some 50 theories is discussed in three steps: historical context, core elements and reception.

Lecture notes

Prior to the lectures, the respective slides are provided as well as primary sources and literature, as preparatory readings (via Moodle). The program is also available online (www.milak.ch).

Literature

Peter Paret, Makers of Modern Strategy. From Machiavelli to the Nuclear Age, Princeton 1986.


853-0302-00L European Integration_O 4 credits 1U+2S R. Szepanski

Only for Public Policy BA.

Abstract

The course (lecture and tutorial) covers the theory, development, and core policy fields of European integration as well as structures and processes of the EU as a decision- and policy-making system.

Objective

The seminar is designed to help students understand the European Union as a particular kind of political system that differs both from the nation-state and from other international organizations. It imparts basic knowledge on the development, institutions, procedures, and policies of the EU and provides an introduction to major approaches to integration theory and political science research on the EU.

Prerequisites / notice

Passive knowledge of English and French are required.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed

Domain C - Social Competencies
Communication assessed

Domain D - Personal Competencies
Creative Thinking assessed

Critical Thinking assessed

853-0101-02L Defense Economics I_O 3 credits 2V M. M. Keupp

Abstract

In terms of structure and content, the event follows the lecturer's book “Militärökonomie” (Military Economics), which is available in two language versions:

- German language: ISBN 978-3-658-06146-3

Objective

* Recognizing parallels and contrasts between business and military thinking;
* Recognize and analyze planned economic systems;
* Understand the link between institutions, human action and economic results.

Content

The contents correspond to sections 1 to 2.2.5 of the above book. The following will be discussed:

1. fundamental military economic problems including historical introduction to the topic
2. the institutional foundations of a military organisation
3. the modern military as a planned economy system
4. actors and stakeholders in the system

Lecture notes

Lecture slides are given to the participants before the first lecture. In addition, the above mentioned book will be handed over to the participants. Participants of the lecture who are not professional officer candidates are requested to obtain the book from the library or bookstore.

Literature

ISBN 978-3-658-06146-3

ISBN 978-3-658-25287-8

Prerequisites / notice

none.
ECTS Reader: Lecturers

Based on the research design prepared in part I of the seminar, candidates write a comprehensive academic term paper. The term paper

Type

The lecture consists of three parts: I. Basics, II. Security policy instruments, III. Consolidation.

Objective

- explain the basic concepts of security law;
- outline the basic constitutional order for Swiss security policy, identify the competences of the Confederation and assess the advantages and disadvantages of this basic order;
- explain and evaluate special legal forms of action;
- distinguish the tasks of security policy actors and assess forms of cooperation;
- derive legal limitations for operations of the armed forces from the Federal Constitution;
- identify the basic principles and individual special aspects of military-civilian cooperation;
- identify the police powers of the armed forces and determine the permissibility of using forms of coercion;
- describe the legal status of members of the armed forces and explain the special responsibility of officers;
- establish the relationship between the actions of state actors and the guarantee of fundamental rights;
- assess current challenges in security law.

Content

The last hour before the examination is reserved for revision and questions.

Lecture notes

- Gianfranco Albertini/Thomas Armbruster/Beat Spörri, Militärisches Einsatzrecht, Zürich 2016 (ISBN 978-3-7255-7080-5; around CHF 89.-)

Other texts are prepared in a reader.

Languages

First Foreign Language

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>853-0416-00L</td>
<td>English, Part III ■ Only for Public Policy BA</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Schweizer</td>
</tr>
</tbody>
</table>

Abstract

The knowledge and skills acquired in the second semester serve as a basis for further improvements in the areas of speaking, listening, reading and writing, which will enable students to enroll for the Cambridge exams. The goal is to reach Council of Europe (CEFR) level C1 or C2 depending on the linguistic proficiency of the students.

Objective

This three-semester English course should enable the participants to successfully use the English language in an international military setting.

Content

- Read, analyse and write military and civilian documents
- Listening comprehension using current radio or TV reports
- Practise speaking with group discussions and short presentations
- Systematic revision and extension of key grammar points
- Systematic acquisition of general and military vocabulary

5. Semester

Remaining Core Courses of the Bachelor's Programme

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>853-0049-00L</td>
<td>Introduction to Constitutional Law in Security Policy</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>R. Müller</td>
</tr>
</tbody>
</table>

Abstract

The lecture deals with questions of competence and the security policy instruments in the federal state, conveys the basic principles of police law and deals with the management of extraordinary situations. Special topics are the army, civil protection, the intelligence service, the legal status of army members, private security providers and cooperation (at home and abroad).

Objective

The students can

- explain the basic concepts of security law;
- outline the basic constitutional order for Swiss security policy, identify the competences of the Confederation and assess the advantages and disadvantages of this basic order;
- explain and evaluate special legal forms of action;
- distinguish the tasks of security policy actors and assess forms of cooperation;
- derive legal limitations for operations of the armed forces from the Federal Constitution;
- identify the basic principles and individual special aspects of military-civilian cooperation;
- identify the police powers of the armed forces and determine the permissibility of using forms of coercion;
- describe the legal status of members of the armed forces and explain the special responsibility of officers;
- establish the relationship between the actions of state actors and the guarantee of fundamental rights;
- assess current challenges in security law.

Content

In the first part, terms of security and police law are introduced, the Swiss security constitution (Confederation and cantons) is explained and the significance of fundamental rights guarantees is shown.

In the second part, the security policy instruments of the Confederation and the cantons are assessed critically. A special focus is placed on the army. In addition to its constitutional anchoring and its tasks, the forms of deployment enshrined in the relevant regulations (e.g. military act) are examined from a legal perspective. Special attention is given to police powers of military forces.

In the third part of the course deals in greater depth with the intelligence service, civil protection, the legal permitted tasks of private security providers and the legal status of military personnel.

The last hour before the examination is reserved for revision and questions.

Lecture notes

- The basic source of the lectures is (purchase recommended):

Literature

The basic source of the lectures is (purchase recommended):
- Gianfranco Albertini/Thomas Armbruster/Beat Spörri, Militärisches Einsatzrecht, Zürich 2016 (ISBN 978-3-7255-7080-5; around CHF 89.-)

853-0038-00L

Swiss Foreign Policy

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>853-0038-00L</td>
<td>Swiss Foreign Policy ■ Only for Public Policy BA</td>
<td>O</td>
<td>3 credits</td>
<td>2V</td>
<td>D. Möckli</td>
</tr>
</tbody>
</table>

Abstract

This course analyzes the foundations and challenges of Swiss foreign policy. After reviewing the history of foreign policy conceptions since the early 20th century, we will discuss the determining factors of Swiss foreign policy and examine, together with guest speakers from the foreign ministry, current international developments and respective foreign policy challenges.

Objective

Students should acquire a sound understanding of Swiss foreign policy and the relevant academic and political debates associated with it.

Content

After a brief introduction to international politics, students will analyze the different levels of the international system. Within the framework of the course, they will develop a strategy for foreign policy by analyzing the role of national interests, the concept of security, and the use of military power. The students will then be able to explore the concept of security within a global context.

Lecture notes

- The required reading will be listed at the beginning of the semester.

Literature

- The course will be supported by an e-learning environment.

853-0321-00L

Advanced Course II (Seminar) ■ Only for Public Policy BA

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>853-0321-00L</td>
<td>Advanced Course II (Seminar) ■ Only for Public Policy BA</td>
<td>O</td>
<td>4 credits</td>
<td>3S</td>
<td>E. Nussio, M. M. Keupp</td>
</tr>
</tbody>
</table>

Abstract

This two-semester course is divided into several groups. A core question relating to the topic of the seminar paper is being developed (I), which will be chosen in coordination and under the guidance of the respective lecturers. Upon conclusion, the paper will be presented in class (II). Based on the qualifications obtained in the Proseminar, a high academic standard is expected.

Objective

- Based on the research design prepared in part I of the seminar, candidates write a comprehensive academic term paper. The term paper should be considered as a good preparation for the BA thesis.
Seminar II builds on the findings of seminar I. Within the broader framework of the overall theme of the seminar (Foreign Policies and Security Strategies of the Great Powers) and based on the approved research design of seminar I, participants write their term paper (in close consultation with the lecturer).

A Reader was provided as part of seminar I (cf. online platform Moodle).

cf. Reader and Reading List Seminar I

Seminar I

German

Introduction to Cybersecurity Politics

M. Dunn Cavelty, F. J. Egloff

3 credits

2G

The lecture is an introduction to global cybersecurity politics. The focus is on the strategic use of cyberspace by state and non-state actors (threats) and different answers to these new challenges (countermeasures).

Participants learn to assess the advantages and disadvantages of cyberspace as a domain for strategic military operations. They understand the technical basics of cyber operations and know how technology and politics are interlinked in this area. They understand the security challenges for and the motivations of states to be active in cyberspace offensively and defensively and they are familiar with the consequences for international politics.

We start with an overview of cybersecurity issues from 1980 to today and look at events and actors responsible for turning cybersecurity matters into a security political issue with top priority. After familiarizing ourselves with the technical basics, we look at different forms of cyberviolence and trends in cyber conflicts (technique in social and political practice). Then, we turn to countermeasures: we compare national cybersecurity strategies, examine international norms building, and scrutinize concepts such as cyber-power and cyber-deterrence (technique in social and political regulatory contexts).

A script with background information and comments on the literature will be made available at the beginning of the semester.

Literature for each session will be available on Moodle.

The lecture is being supported by a website on Moodle.

Social Psychology of Groups

T. Heilmann

3 credits

2V

Basic social psychological topics are elaborated, presented, and discussed in the most application-oriented way.

You are able to recognize and explain various social psychological aspects and factors and to evaluate them in your everyday decisions in terms of planning, content and operations. This means you will be able to assess when various social psychological aspects may play a role in your everyday work. And you are able to assess what this may subsequently mean for your work or leadership processes.


1) Führungspychologie: Kurzer Einblick in neuere Führungstheorien.

2) Destructive Führung: Was sollten wir nicht machen?

3) Soziale Kognition: Warum und auf Basis welcher wenigen Informationen wir sehr schnell Urteile über Personen treffen.

4) Soziale Wahrnehmung/Attribution: Wie erklären wir uns, dass sich jemand im Alltag in gewisser Art und Weise verhält?

5) Diversity & Frauen & Führung: Woran kann es liegen, dass weibliche Führungskräfte besondere Herausforderungen bei der Ausübung von Führung haben?

6) Sozialer Einfluss: Welche Normen erleben Sie beim Militär? Und wie leiten diese Erwartungen unser Verhalten im Berufsalltag?

7) Gruppenpsychologie: Was heisst "Gruppe"? Wie entwickeln sich (militärische) Gruppen, z.B. in der RS? Welche Prozesse können zwischen Gruppen geschehen?


9) Überzeugungsstrategien
Literature


Languages

Second Foreign Language

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>853-0402-00L</td>
<td>German, Part II</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Schweizer</td>
</tr>
<tr>
<td>853-0404-00L</td>
<td>French, Part II</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Schweizer</td>
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</tbody>
</table>

Bachelor's Colloquium and Bachelor's Thesis

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>853-0315-00L</td>
<td>BA Colloquium</td>
<td>O</td>
<td>2</td>
<td>2K</td>
<td>F. Schimmelfennig</td>
</tr>
</tbody>
</table>
The Role of Technology in National and International Security Policy

The lecture provides an introduction to the role of security and military technologies in the formulation and implementation of national and international security policies. The focus is on challenges posed by new and developing technologies, the transformation of military capabilities, and the question of regulation.

Participants will gain an in-depth overview of the many ways in which technology is becoming part of security policies and practices, in both civilian and military contexts.

Content
- Introduction to sport psychology
- Cognitions in sports: mental rehearsal and mental training
- Emotions and stress
- Motivation: goal-setting in sports
- Career and career transition in elite sport
- Coach-Athlete-Interaction
- Psychological aspects of sport-injury rehabilitation
- Group dynamics in sport

Lecture notes
Instructional materials for each course will be made available to students. All lecture materials will be available to students on Moodle.

Literature

376-1127-00L Sociology of Sport
W 2 credits 2V R. Bürgi, M. Lamprecht

Abstract
These lectures deal with the current changes in society and sport and provide an overview of the many different problems and perspectives of sport sociology.

Objective
The lectures set out to:
- present the different dimensions, functions and interrelationships of present-day sport
- provide an introduction to the central theories and models of (sport) sociology
- show how far sport reflects society and how it changes and becomes more differentiated in the process
- take current examples to highlight the sociological view of sport.

Content
Sport and social change: developments and trends
The economy and the media: dependencies, consequences, scandals
Social inequalities and distinctions: gender differences and group behavior
Conflicts and politics: sports organizations, doping, violence

Lecture notes
Selected materials for the lecture are available on the Moodle platform.

Literature

A detailed program with additional references will be delivered at the beginning of the lecture.

851-0589-00L Technology and Innovation for Development
W 3 credits 2V P. Aerni

Abstract
Technological change plays a crucial role in efforts to create a more sustainable future. In this context, policy decision makers must design rules that minimize its risks and maximize its benefits for society at large. The course discusses this challenge from an interdisciplinary perspective taking into account legal, economic, historical, development and environmental aspects.

Objective
- to recognize the challenges and opportunities of technological change in terms of sustainable development
- to become familiar with policy instruments to promote innovation
- to improve understanding of political decision-making processes in the regulation of science & technology
- improved understanding of the role of science and technology in the context of human and societal development

Content
Science and Technology Policy is normally associated with the improvement of national competitiveness; yet, it is also an integral part of effective environmental and development policies.

The course will discuss the challenges and opportunities of technological change in terms of sustainable development and show how public policy on the national and the international level is responding to this change.

In this context, students are to become familiar with the basic principles of political economy and New Growth Theory and how such theories help explain political decisions as well as political outcomes in the area of Science, Technology and Innovation. State interventions are either designed to regulate (e.g. environmental regulations, anti-trust law) or facilitate (e.g. intellectual property rights protection, public investment in R&D and technical education, technology transfer) technological change. This will be illustrated by looking at different industries and different national systems of innovation. Subsequently the positive and negative consequences for society and the natural environment will be discussed from a short-term and a long-term perspective.

Lecture notes
Reader with issue-specific articles. E-version is partly available under:
https://www.ethz.ch/content/specialinterest/gess/cis/international-relations/en/teaching/materials/tech.html
The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

Prerequisites / notice
The 2-hour course (5-7 p.m.) will be held as a series of lectures. The course materials will be available in form of an electronic Reader at the beginning of the semester. The class will be taught in English. Students will be asked to make a contribution in class choosing one out of three options:
(a) presentation in class (15 Minutes) based on a paper to be discussed on a particular day in class
(b) review paper based on a selected publication in the course material
(c) preparation of questions for a selected invited speaker, and subsequent submission of protocol about the content of the talk and the discussion

In addition, they will have to pass a written test at the end of the course in order to obtain 3 credit points in the ECTS System. In the final mark (a) will have a weight of 40% and (b) 60%.

860-0023-00L International Environmental Politics
Particularly suitable for students of D-ITET, D-USYS

<table>
<thead>
<tr>
<th>W</th>
<th>3 credits</th>
<th>2V</th>
<th>T. Bernauer</th>
</tr>
</thead>
</table>

Objective
This course focuses on the conditions under which problem solving efforts in international environmental politics emerge and the conditions under which such efforts and the respective public policies are effective.

The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

Literature

Autumn Semester 2021
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This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

- **Lectures**: A pre-recorded lecture by Prof. Bernauer, available via Moodle.
- **Assignments**: Reading assignments, available via Moodle, for a few selected course units.
- **Meetings**: Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

### Prerequisites / Literature / Lecture notes

- **Selected readings from the book and additional learning materials** will be available on the course Moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15262

### Content

This course is an introduction to the critical management skills involved in planning, organizing, leading and controlling an organization. By the end of this course, students will understand management as a set of skills, processes, tools and methods that enable organizations to achieve their goals and to coordinate routine operations in order to meet evolving customers' and societal needs. The students will achieve these goals by being able to:

- Analyze organizations as open systems, and describe their critical elements,
- Apply conceptual tools and methods that help to analyze or approach the critical elements,
- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

Analyze organizations as open systems, and describe their critical elements,

- Compare different notions of organizational performance, and explain why they matter,
- Discuss the relationships that connect the critical elements of an organization on the basis of real cases,
- Explain how change, internally or externally initiated, impact such relationships

### Objective

This course is an introduction to critical management skills involved in planning, organizing, leading and controlling an organization. This course follows a 'systemic' view of organizations and adopts the congruence model as a framework to analyze the critical, interconnected elements of organizations: Input (i.e., from external environment), strategy, people, work, formal and informal structure of the organization, and its outputs. In this course we will introduce these critical elements and learn how managers can analyze and approach these elements by means of different conceptual tools and methods in order to achieve performance. We will furthermore discuss the relationships that connect the critical elements together by means of real-life cases, whereby the focus will be on the critical reflection of particular cases of fits and misfits between those elements and on the application of a selection of tools and methods.

### Lecture notes

- **Abstract**: Introduction to Management, W 3 credits, 2G, Z. Zagorac-Uremovic, J. O'Neill

### Literature

- **Content**: The content of the course will rely on different readings, cases and selected chapters of following book: Dess, G., McNamara, G., Eisner, A., & Lee, SH. 2018. Strategic Management: Text and Cases. McGraw Hill.

### Prerequisites / notice

Throughout the course different session preparation assignments, like book chapters or case studies will be handed out to the students on moodle. This preparation is required to participate in the lectures. The final exam of the present course is online exam.

The final exam is requested for all types of students (BSc, MSc, MA, PhD, and Exchange students). It is not possible to retake the exam within the same term or academic year.

We strongly recommend Exchange students to take it into consideration when selecting the courses to attend.

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**Data**: 14.12.2021 12:41

**Autumn Semester 2021**

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Projects are not only the base of work in modern enterprises but also the primary type of cooperation with customers. Students of ETH will be assessed. Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

101-0985-00L Social Intercourse with Current Environmental Risks

Abstract
The lecture treats the social intercourse with risks of technical systems. The notion of risk and the perception of risk are discussed by case studies (e.g. nanotechnology) and socio-political instruments for decision-making are presented. Methods that are presented can be applied to deal with environmental risks and how they can be used for sustainable innovation.

Objective
- Getting acquainted to the extended risk concept
- Evaluation of the risks caused by technology within the societal context
- Knowledge about the mode science and society handle current environmental risks (examples gene- and nanotechnology)
- Knowledge about handling risks (e.g. precautionary principle, protection goal, damage definition, ethics)
- Knowledge about possibilities for sustainable innovation

Content
- Risks and technical systems (risk categories, risk perception, risk management)
- Implementation with case studies (nanotechnology)
- Decision making (technology assessment, cost/benefit analysis etc.)
- The role of the media
- Prospects for future developments

Lecture notes
Copies of slides and selected documents will be distributed.

Prerequisites / notice
The lecture is held biweekly (for 2 hours). The dates are 3.9.; 30.9. (instead of 7.10); 21.10; 4.11.; 18.11.; 2.12.; 16.12.

701-0707-00L Environmental Ethics

Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

Content
- Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarisation with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

Lecture notes
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

Literature
- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neill et al., Environmental Values, 2008

Generel introductions:
- Marcus Döwelier et. al (Hrsg.), Handbuch Ethik, 2. Auflage, Stuttgart (Metzler Verlag), 2006
- Johann S. Ach et. al (Hrsg.), Grundkurs Ethik 1. Grundlagen, Paderborn (mentis) 2008
Introduction to environmental management / environmental management systems will be provided by a CD or mail.

Overview on environmental management and environmental management systems, general methods and principles.

Participants of the course Research Ethics will

Students are able to identify and critically evaluate moral arguments, to analyse and to solve moral dilemmas considering different normative perspectives and to create their own well-justified reasoning for taking decisions to the kind of ethical problems a scientist is likely to encounter during the different phases of biomedical research.

Participants of the course Research Ethics will

- Develop an understanding of the role of certain moral concepts, principles and normative theories related to scientific research;
- Improve their moral reasoning skills (such as identifying and evaluating reasons, conclusions, assumptions, analogies, concepts and principles), and their ability to use these skills in assessing other people’s arguments, making decisions and constructing their own reasoning to the kinds of ethical problems a scientist is likely to encounter;

I. Introduction to Moral Reasoning

1. Ethics - the basics
   - 1.1 What ethics is not…
   - 1.2 Recognising an ethical issue (awareness)
   - 1.3 What is ethics? Personal, cultural and ethical values, principles and norms
   - 1.4 Ethics: a classification
   - 1.5 Research Ethics: what is it and why is it important?

2. Normative Ethics
   - 2.1 What is normative ethics?
   - 2.2 Types of normative theories – three different ways of thinking about ethics: Virtue theories, duty-based theories, consequentialist theories
   - 2.3 The plurality of normative theories (moral pluralism);
   - 2.4 Roles of normative theories in “Research Ethics”

3. Decision making: How to solve a moral dilemma
   - 3.1 How (not) to approach ethical issues
   - 3.2 What is a moral dilemma?
   - 3.3 Methods of making ethical decisions
   - 3.4 Is there a “right” answer?

II. Research Ethics - Internal responsibilities

1. Integrity in research and research misconduct
   - 1.1 What is research integrity and why is it important?
   - 1.2 What is research misconduct?
   - 1.3 Questionable/Detrimental Research Practice (QRP/DRP)
   - 1.4 What is the incidence of misconduct?
   - 1.5 What are the factors that lead to misconduct?
   - 1.6 Responding to research wrongdoing
   - 1.7 The process of dealing with misconduct
   - 1.8 Approaches to misconduct prevention and for promoting integrity in research

2. Data Management
   - 2.1 Data collection and recordkeeping
   - 2.2 Analysis and selection of data
   - 2.3 The (mis)representation of data
   - 2.4 Ownership of data
   - 2.5 Retention of data
   - 2.6 Sharing of data
   - 2.7 The ethics of big data

3. Publication ethics / Responsible publishing
   - 3.1 Background
   - 3.2 Criteria for being an author
   - 3.3 Ordering of authors
   - 3.4 Publication practices

III. Research Ethics – External responsibilities

1. Research involving human subjects
   - 1.1 History of research with human subjects
   - 1.2 Basic ethical principles – The Belmont Report
   - 1.3 Requirements to make clinical research ethical
   - 1.4 Social value and scientific validity

2. Social responsibility
   - 2.1 What is social responsibility?
   - 2.2 Participation in public discussions

3. Publication ethics
   - 3.1 Introduction to publication ethics
   - 3.2 Case study – Censuring science?
   - 3.3 Transmission studies for avian flu

Lecture notes

Course material (handouts, case studies, exercises, surveys and papers) will be available during the lectures and on the course homepage.
Prerequisites / notice
What are the requirements?
First and foremost your strong willingness to seriously achieve the main learning outcomes as indicated in the Course Catalogue (specific learning outcomes for each module will be provided at the beginning of the course). For successfully completing the course Research Ethics, the following commitment is absolutely necessary (but not sufficient) (observed success factors for many years!):
1. Your regular presence is absolutely required (so please no double, parallel enrollment for courses taking place at the identical time!) connected with your active participation during class, e.g., taking notes, contributing to discussions (in group as well as in plenary class), solving exercises.
2. Having the willingness and availability of the necessary time for regularly preparing the class (at least 1 hour per week, probably even more...).

Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| | Decision-making | assessed |
| | Problem-solving | assessed |
| Domain C - Social Competencies | Communication | assessed |
| | Cooperation and Teamwork | assessed |
| Domain D - Personal Competencies | Creative Thinking | assessed |
| | Critical Thinking | assessed |
| | Integrity and Work Ethics | assessed |
| | Self-awareness and Self-reflection | assessed |

851-0861-01L Arabic I A1.1
No enrolment to this course at ETH Zurich. Book the corresponding course directly at "Language Center of UZH and ETH Zürich".

Course fees:

Registration dates:

Abstract
Arabic I leads to A1.1 level on the Common European Framework of Reference for Languages. Arabic I is the first part (A1.1 level) of a four-semester Arabic course. The goal of the course is for participants to acquire basic language skills in speaking, listening comprehension, and the reading and writing of Arabic script.

Objective
Participants are able to use the Arabic language adequately in selected areas. The focus is on speaking; reading and listening comprehension at A1.1 level on the Common European Framework of Reference for Languages; learning Arabic script; and the development of cultural competence. The following content areas are embedded in various communicative tasks: Greeting each other, introducing yourself and speaking about yourself (personal and professional identity, place of residence), making simple phone calls, requesting information, and making appointments.

Public Policy Bachelor - Key for Type

| Dr | Suitable for doctorate | W | Eligible for credits |
| O | Compulsory | E- | Recommended, not eligible for credits |
| W+ | Eligible for credits and recommended | Z | Courses outside the curriculum |

Key for Hours

| V | lecture |
| G | lecture with exercise |
| U | exercise |
| S | seminar |
| K | colloquium |
| P | practical/laboratory course |
| A | independent project |
| D | diploma thesis |
| R | revision course / private study |

ECTS
European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
**Master Studies (Programme Regulations 2020)**

**Core Courses**

### Statistical Modelling

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-3622-00L</td>
<td>Statistical Modelling</td>
<td>W</td>
<td>8 credits</td>
<td>4G</td>
<td>C. Heinze-Deml</td>
</tr>
<tr>
<td>Abstract</td>
<td>In regression, the dependency of a random response variable on other variables is examined. We consider the theory of linear regression with one or more covariates, high-dimensional linear models, nonlinear models and generalized linear models, robust methods, model choice and nonparametric models. Several numerical examples will illustrate the theory.</td>
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<tr>
<td>Objective</td>
<td>Introduction into theory and practice of a broad and popular area of statistics, from a modern viewpoint.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This is the course unit with former course title &quot;Regression&quot;. Credits cannot be recognised for both courses 401-3622-00L Statistical Modelling and 401-0649-00L Applied Statistical Regression in the Mathematics Bachelor and Master programmes (to be precise: one course in the Bachelor and the other course in the Master is also forbidden).</td>
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<tr>
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</thead>
<tbody>
<tr>
<td>401-4623-00L</td>
<td>Time Series Analysis</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>F. Balabdaoui</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course offers an introduction into analyzing times series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.</td>
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<tr>
<td>Objective</td>
<td>The goal of the course is to have a good overview of the different types of time series and the approaches used in their statistical analysis.</td>
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<tr>
<td>Content</td>
<td>This course treats modeling and analysis of time series, that is random variables which change in time. As opposed to the i.i.d. framework, the main feature exhibited by time series is the dependence between successive observations.</td>
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<tr>
<td>Literature</td>
<td>The main reference for this course is the book &quot;Introduction to Time Series and Forecasting&quot;, by P. J. Brockwell and R. A. Davis</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Basic knowledge in probability and statistics</td>
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### Applied Statistics

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental Design</td>
<td>W</td>
<td>5 credits</td>
<td>2V+1U</td>
<td>L. Meier</td>
</tr>
<tr>
<td>Abstract</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td>Objective</td>
<td>Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the software R.</td>
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<tr>
<td>Content</td>
<td>Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.</td>
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</table>

### Mathematical Statistics

The two core courses Fundamentals of Mathematical Statistics (401-3621-00L) and Likelihood Inference (401-8623-00L) are similar in content. Therefore only one of them can be recognised towards the Master's degree in the core course area »Mathematical Statistics«.

<table>
<thead>
<tr>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>401-3621-00L</td>
<td>Fundamentals of Mathematical Statistics</td>
<td>W</td>
<td>10 credits</td>
<td>4V+1U</td>
<td>S. van de Geer</td>
</tr>
<tr>
<td>Abstract</td>
<td>The course covers the basics of inferential statistics.</td>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-8623-00L</td>
<td>Likelihood Inference (University of Zurich)</td>
<td>W</td>
<td>5 credits</td>
<td>3G</td>
<td>University lecturers</td>
</tr>
<tr>
<td>Abstract</td>
<td>No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student. UZH Module Code: STA402</td>
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</tr>
<tr>
<td>Notice</td>
<td>Mind the enrolment deadlines at UZH: <a href="https://www.uzh.ch/cmsssl/en/studies/application/deadline">https://www.uzh.ch/cmsssl/en/studies/application/deadline</a> s.html</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Overview over the basics of likelihood inference.</td>
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</tbody>
</table>

### Subject Specific Electives
### 401-3601-00L Probability Theory

**Type:** W  
**ECTS:** 10  
**Hours:** 4V+1U  
**Lecturers:** W. Werner

**Title:** At most one of the three course units (Bachelor Core Courses)

**Abstract:** Basics of probability theory and the theory of stochastic processes in discrete time

**Objective:** This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, series of independent random variables, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

**Content:** This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

**Prerequisites / notice**

- Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

**Literature**

- H. Bauer, Probability Theory, de Gruyter 1996
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

**Lecture notes**

A script will be available in electronic form.

**Course:**

- Number: 401-3601-00L
- Title: Probability Theory
- Type: W
- ECTS: 10
- Hours: 4V+1U
- Lecturers: W. Werner

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### 401-3627-00L High-Dimensional Statistics

**Type:** W  
**ECTS:** 4  
**Hours:** 2V  
**Lecturers:** P. L. Bühlmann

**Title:** “High-Dimensional Statistics” deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.

**Abstract:** Knowledge of methods and basic theory for high-dimensional statistical inference

**Objective:** Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and 1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling

**Content:** This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned:

- Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).

**Prerequisites / notice**

Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

**Literature**

- H. Bauer, Probability Theory, de Gruyter 1996
- J. Jacod and P. Protter, Probability essentials, Springer 2004
- D. Williams, Probability with martingales, Cambridge University Press 1991

**Lecture notes**

A script will be available in electronic form.

**Course:**

- Number: 401-3627-00L
- Title: High-Dimensional Statistics
- Type: W
- ECTS: 4
- Hours: 2V
- Lecturers: P. L. Bühlmann

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### 401-3612-00L Stochastic Simulation

**Type:** W  
**ECTS:** 5  
**Hours:** 3G  
**Lecturers:**

**Title:** Does not take place this semester.

**Abstract:** This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.

**Objective:** Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.

**Content:** Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics). Generation of uniform random variables. Generation of random variables with arbitrary distributions (quantile transform, accept-reject, importance sampling), simulation of Gaussian processes and diffusions. The precision of simulations, methods for variance reduction. Introduction to Markov chains and Markov chain Monte Carlo (Metropolis-Hastings, Gibbs sampler, Hamiltonian Monte Carlo, reversible jump MCMC).

**Prerequisites / notice**

Knowledge of basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

**Literature**


**Lecture notes**

A script will be available in English.

**Course:**

- Number: 401-3612-00L
- Title: Stochastic Simulation
- Type: W
- ECTS: 5
- Hours: 3G

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### 401-4633-00L Data Analytics in Organisations and Business

**Type:** W  
**ECTS:** 5  
**Hours:** 2V+1U  
**Lecturers:** I. Flückiger

**Title:** Framing the Business Problem

**Abstract:** On the end-to-end data analytics process in organizations & businesses and how to transform data into insights for fact-based decisions. Presentation of the process from the beginning with framing the business problem to presenting the results and making decisions using data analytics. For each topic, case studies from the financial service, healthcare, and retail sectors will be given. This course aims to give the students an understanding of the data analytics process in the business world, with a particular focus on the skills and techniques used besides the technical skills. The student will become familiar with the "business language," current problems, and thinking in organizations and business and tools used.

**Objective:** Framing the Business Problem

**Content:** Framing the Business Problem

**Lecture notes**

The lecture's presentation slides will be provided.

**Course:**

- Number: 401-4633-00L
- Title: Data Analytics in Organisations and Business
- Type: W
- ECTS: 5
- Hours: 2V+1U
- Lecturers: I. Flückiger

---
The students will learn about methods of kernel smoothing and application of concepts to data. The aim will be to build sufficient interest in
1G
F. Sigrist
Knowledge of the Elements and the process of a sample survey. Understanding of the paradigm of random samples. Knowledge of simple
Bayesian Statistics
Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic
Brief summaries or outlines of some of the lecture material will be posted at https://www.wsl.ch/en/employees/ghosh.html.
W
1G
M. Mächler
Introduction to the statistical methods of survey research
References:
The course provides the second part an introduction to the statistical software R (https://www.r-project.org/) for scientists. R is free
software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the
programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.
Part II of the course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options
- Extending basic R: packages
Lecture notes
The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org
Prerequisites / notice
Basic knowledge of R equivalent to "Using R .. (part I)" ( = 401-6215-00L ) is a prerequisite for this course.
The course resources will be provided via the Moodle web learning platform.
As from FS 2019, subscribing via Mystudies should "automatically" make you a student participant of the Moodle course of this lecture, which is at
https://moodle-app2.let.ethz.ch/course/view.php?id=15522
401-0627-00L
Smoothing and Nonparametric Regression with Examples
S. Beran-Ghosh
W 4 credits  2G
Abstract
Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic theory, optimal bandwidth selection, data driven algorithms and some special topics. Examples from environmental research will be used for motivation, but the methods will also be applicable elsewhere.
Objective
The students will learn about methods of kernel smoothing and application of concepts to data. The aim will be to build sufficient interest in the topic and intuition as well as the ability to implement the methods to various different datasets.
Content
Rough Outline:
- Parametric estimation methods: selection of important results
  - Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
  - Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
  - Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.
Lecture notes
Brief summaries or outlines of some of the lecture material will be posted at https://www.wsl.ch/en/employees/ghosh.html.
LOG IN: In order to have access to the posted notes, you will need the course user id & the password. These will be given out on the first day of the lectures.
Literature
References:
- Statistical Inference, by S.D. Silvey, Chapman & Hall.
- Density Estimation, by B.W. Silverman, Chapman and Hall.
- Nonparametric Simple Regression, by J. Fox, Sage Publications.
Additional references will be given out in the lectures.
Prerequisites / notice
Prerequisites: A background in Linear Algebra, Calculus, Probability & Statistical Inference including Estimation and Testing.
447-6289-00L
Sampling Surveys
Does not take place this semester.
Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.
Abstract
The elements of a sample survey are explained. The most important classical sample designs (simple random sampling and stratified random sampling) with their estimation procedures and the use of auxiliary information including the Horvitz-Thompson estimator are introduced. Data preparation, non-response and its treatment, variance estimation and analysis of survey data is discussed.
Objective
Knowledge of the Elements and the process of a sample survey. Understanding of the paradigm of random samples. Knowledge of simple random sampling and stratified random sampling and capability to apply the corresponding methods. Knowledge of further methods of sampling and estimation as well as data preparation and analysis.
Lecture notes
Introduction to the statistical methods of survey research
Abstract
Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

Objective
Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content
Topics that we will discuss are:
- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods)

Lecture notes
A script will be available in English.

Literature

Additional references will be given in the course.

Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

401-3901-00L
Linear & Combinatorial Optimization
W 11 credits 4V+2U R. Zenklusen

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature

Prerequisites / notice
Solid background in linear algebra.

401-4944-20L
Mathematics of Data Science
W 8 credits 4G A. Bandeira

Abstract
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective
Introduction to various mathematical aspects of Data Science.

Content
These topics lie in overlaps of (Applied) Mathematics with: Computer Science, Electrical Engineering, Statistics, and/or Operations Research. Each lecture will feature a couple of Mathematical Open Problem(s) related to Data Science. The main mathematical tools used will be Probability and Linear Algebra, and a basic familiarity with these subjects is required. There will also be some (although knowledge of these tools is not assumed) Graph Theory, Representation Theory, Applied Harmonic Analysis, among others. The topics treated will include Dimension reduction, Manifold learning, Sparse recovery, Random Matrices, Approximation Algorithms, Community detection in graphs, and several others.

Lecture notes

Prerequisites / notice
The main mathematical tools used will be Probability, Linear Algebra (and real analysis), and a working knowledge of these subjects is required. In addition to these prerequisites, this class requires a certain degree of mathematical maturity—including abstract thinking and the ability to understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.
A. Bandeira and H. Bölcskei
### Abstract

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

### Objective

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solve modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

### Content

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- **Fundamentals:**
  - What is data?
  - Bayesian Learning
  - Computational learning theory

- **Supervised learning:**
  - Ensembles: Bagging and Boosting
  - Max Margin methods
  - Neural networks

- **Unsupervised learning:**
  - Dimensionality reduction techniques
  - Clustering
  - Mixture Models
  - Non-parametric density estimation
  - Learning Dynamical Systems

### Literature


### Prerequisites / notice

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-3005-00L</td>
<td>Natural Language Processing</td>
<td>5</td>
<td>2V+2U+1A</td>
<td>R. Cotterell</td>
</tr>
<tr>
<td>227-0423-00L</td>
<td>Neural Network Theory</td>
<td>4</td>
<td>2V+1U</td>
<td>H. Bölcskei</td>
</tr>
<tr>
<td>401-6282-00L</td>
<td>Statistical Analysis of High-Throughput Genomic and Transcriptomic Data (University of Zurich)</td>
<td>5</td>
<td>3G</td>
<td>H. Rehrauer, M. Robinson</td>
</tr>
</tbody>
</table>
**Abstract**
A range of topics will be covered, including basic molecular biology, genomics technologies and in particular, a wide range of statistical and computational methods that have been used in the analysis of DNA microarray and high throughput sequencing experiments.

**Objective**
- Understand the fundamental "scientific process" in the field of Statistical Bioinformatics
- Be equipped with the skills/tools to preprocess genomic data (Unix, Bioconductor, mapping, etc.) and ensure reproducible research (Sweave)
- Have a general knowledge of the types of data and biological applications encountered with microarray and sequencing data
- Gain the ability to apply statistical methods/knowledge/software to a collaborative biological project
- Gain the ability to critically assess the statistical bioinformatics literature
- Write a coherent summary of a bioinformatics problem and its solution in statistical terms

**Content**
Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; Controlling error rates of statistical tests (FPR versus FDR versus FWER); limma (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

**Lecture notes**
Lecture notes, published manuscripts

**Prerequisites / notice**
Prerequisites: Basic knowledge of the programming language R, sufficient knowledge in statistics

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**401-8625-00L Clinical Biostatistics (University of Zurich)**

*No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.*

UZH Module Code: STA404

Mind the enrolment deadlines at UZH:

**Abstract**
Discussion of the different statistical methods that are used in clinical research.

**Content**
Discussion of the different statistical methods that are used in clinical research. Among other subjects the following will be introduced: sample size calculation, randomization and blinding, analysis of clinical trials (parallel groups design, analysis of covariance, crossover design, equivalence studies), intention-to-treat analysis, multiple testing, group sequential methods, adaptive designs, diagnostic studies, and agreement studies.

**Literature**

**Prerequisites / notice**
Basic knowledge of the programming language R, sufficient knowledge in calculus, linear algebra, probability, statistics

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**263-3210-00L Deep Learning**

*Number of participants limited to 320.*

**Abstract**
Deep learning is an area within machine learning that deals with algorithms and models that automatically induce multi-level data representations.

**Objective**
In recent years, deep learning and deep networks have significantly improved the state-of-the-art in many application domains such as computer vision, speech recognition, and natural language processing. This class will cover the mathematical foundations of deep learning and provide insights into model design, training, and validation. The main objective is a profound understanding of why these methods work and how. There will also be a rich set of hands-on tasks and practical projects to familiarize students with this emerging technology.
This is an advanced level course that requires some basic background in machine learning. More importantly, students are expected to have a very solid mathematical foundation, including linear algebra, multivariate calculus, and probability. The course will make heavy use of mathematics and is not (!) meant to be an extended tutorial of how to train deep networks with tools like Torch or Tensorflow, although that may be a side benefit.

The participation in the course is subject to the following condition:
- Students must have taken the exam in Advanced Machine Learning (252-0535-00) or have acquired equivalent knowledge, see exhaustive list below:

  Advanced Machine Learning
  https://ml2.inf.ethz.ch/courses/aml/

  Computational Intelligence Lab
  http://da.inf.ethz.ch/teaching/2019/CIL/

  Introduction to Machine Learning
  https://las.inf.ethz.ch/teaching/introml-S19

  Statistical Learning Theory
  http://ml2.inf.ethz.ch/courses/slt/

  Computational Statistics
  https://stat.ethz.ch/lectures/ss19/comp-stats.php

  Probabilistic Artificial Intelligence
  https://las.inf.ethz.ch/teaching/pai-f18

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Detting</td>
</tr>
</tbody>
</table>

Abstract
- This course introduces core modeling techniques and algorithms from machine learning, optimization and control for reasoning and decision making under uncertainty, and study applications in areas such as robotics.

Objective
- How can we build systems that perform well in uncertain environments? How can we develop systems that exhibit "intelligent" behavior, without prescribing explicit rules? How can we build systems that learn from experience in order to improve their performance? We will study core modeling techniques and algorithms from statistics, optimization, planning, and control and study applications in areas such as robotics. The course is designed for graduate students.

Content
- Probability
- Probabilistic inference (variational inference, MCMC)
- Bayesian learning (Gaussian processes, Bayesian deep learning)
- Probabilistic planning (MDPs, POMDPs)
- Multi-armed bandits and Bayesian optimization
- Reinforcement learning

Prerequisites / notice
- Solid basic knowledge in statistics, algorithms and programming.
- The material covered in the course "Introduction to Machine Learning" is considered as a prerequisite.

Free Electives

Several further courses offered at the University of Zurich belong to the curriculum of the Master’s Programme in Statistics. With the consent by the Advisor (http://stat.ethz.ch/~kalisch/) such a course is eligible as a free elective.

Master Studies (Programme Regulations 2014)

Core Courses

In each subject area, the core courses offered are normally mathematical as well as application-oriented in content. For each subject area, only one of these is recognised for the Master degree.

Regression

<table>
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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Detting</td>
</tr>
</tbody>
</table>

Abstract
- This course offers a practically oriented introduction into regression modeling methods. The basic concepts and some mathematical background are included, with the emphasis lying in learning "good practice" that can be applied in every student's own projects and daily work life. A special focus will be laid in the use of the statistical software package R for regression analysis.

Objective
- The students acquire advanced practical skills in linear regression analysis and are also familiar with its extensions to generalized linear modeling.

Content
- The course starts with the basics of linear modeling, and then proceeds to parameter estimation, tests, confidence intervals, residual analysis, model choice, and prediction. More rarely touched but practically relevant topics that will be covered include variable transformations, multicollinearity problems and model interpretation, as well as general modeling strategies.
- The last third of the course is dedicated to an introduction to generalized linear models: this includes the generalized additive model, logistic regression for binary response variables, binomial regression for grouped data and poisson regression for count data.

Lecture notes
- A script will be available.

Literature
- Faraway (2005): Linear Models with R
- Faraway (2006): Extending the Linear Model with R
- Draper & Smith (1998): Applied Regression Analysis
- Fox (2008): Applied Regression Analysis and GLMs
- Montgomery et al. (2006): Introduction to Linear Regression Analysis

Prerequisites / notice
- The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software package R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L "Applied Statistical Regression" and 401-3622-00L “Statistical Modelling” are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.
This course offers an introduction into analyzing time series, that is observations which occur in time. The material will cover Stationary Models, ARMA processes, Spectral Analysis, Forecasting, Nonstationary Models, ARIMA Models and an introduction to GARCH models.

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

"No course offerings in this semester."
This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields. Examples of simulations in different fields (computer science, statistics, statistical mechanics, operations research, financial mathematics).

### Literature

- S. van de Geer, High-Dimensional Statistics: Methods, Theory and Applications, Springer Verlag

A script will be available in English.

### Prerequisites / notice

Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).

### Specialization Areas and Electives

#### Statistical and Mathematical Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>401-3601-00L</td>
<td>Probability Theory</td>
<td>W</td>
<td>10</td>
<td>4+1U</td>
<td>W. Werner</td>
</tr>
<tr>
<td>Abstract</td>
<td>Basics of probability theory and the theory of stochastic processes in discrete time</td>
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<tr>
<td>Objective</td>
<td>This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned: Basics in measure theory, series of independent random variables, weak convergence, characteristic functions, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).</td>
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</tr>
<tr>
<td>Content</td>
<td>This course presents the basics of probability theory and the theory of stochastic processes in discrete time. The following topics are planned: Basics in measure theory, random series, law of large numbers, weak convergence, characteristic functions, central limit theorem, conditional expectation, martingales, convergence theorems for martingales, Galton Watson processes, Markov chains (classification and convergence results).</td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>will be available in electronic form.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
H. Bauer, Probability Theory, de Gruyter 1996  
J. Jacod and P. Protter, Probability essentials, Springer 2004  
A. Klenke, Wahrscheinlichkeitstheorie, Springer 2006  
D. Williams, Probability with martingales, Cambridge University Press 1991 |

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<tr>
<th>Number</th>
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<th>Hours</th>
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</tr>
</thead>
<tbody>
<tr>
<td>401-3627-00L</td>
<td>High-Dimensional Statistics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>P. L. Bühlmann</td>
</tr>
<tr>
<td>Abstract</td>
<td>&quot;High-Dimensional Statistics&quot; deals with modern methods and theory for statistical inference when the number of unknown parameters is of much larger order than sample size. Statistical estimation and algorithms for complex models and aspects of multiple testing will be discussed.</td>
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<tr>
<td>Objective</td>
<td>Knowledge of methods and basic theory for high-dimensional statistical inference</td>
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<tr>
<td>Content</td>
<td>Lasso and Group Lasso for high-dimensional linear and generalized linear models; Additive models and many smooth univariate functions; Non-convex loss functions and ℓ1-regularization; Stability selection, multiple testing and construction of p-values; Undirected graphical modeling</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Knowledge of basic concepts in probability theory, and intermediate knowledge of statistics (e.g. a course in linear models or computational statistics).</td>
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#### Stochastic Simulation

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-3612-00L</td>
<td>Stochastic Simulation</td>
<td>W</td>
<td>5</td>
<td>3G</td>
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</tr>
<tr>
<td>Abstract</td>
<td>This course provides an introduction to statistical Monte Carlo methods. This includes applications of simulations in various fields (Bayesian statistics, statistical mechanics, operations research, financial mathematics), algorithms for the generation of random variables (accept-reject, importance sampling), estimating the precision, variance reduction, introduction to Markov chain Monte Carlo.</td>
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<tr>
<td>Objective</td>
<td>Stochastic simulation (also called Monte Carlo method) is the experimental analysis of a stochastic model by implementing it on a computer. Probabilities and expected values can be approximated by averaging simulated values, and the central limit theorem gives an estimate of the error of this approximation. The course shows examples of the many applications of stochastic simulation and explains different algorithms used for simulation. These algorithms are illustrated with the statistical software R.</td>
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<tr>
<td>Lecture notes</td>
<td>A script will be available in English.</td>
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</tbody>
</table>
### 401-4633-00L Using R for Data Analysis and Graphics (Part I)

**Abstract**
The course provides the first part of an introduction to the statistical software R. Topics include data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions.

**Prerequisites / notice**
Basic knowledge of R equivalent to "Using R... (Part I)" (= 401-6215-00L) is a prerequisite for this course.

**Objective**
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options;
- Extending basic R: packages

**Content**
The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www rstudio.org

**Lecture notes**
An Introduction to R. [http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf](http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf)

**Prerequisites / notice**
Basic knowledge of R equivalent to "Using R... (Part I)" (= 401-6215-00L) is a prerequisite for this course.

### 401-4634-00L Using R for Data Analysis and Graphics (Part II)

**Abstract**
The course provides the second part of an introduction to the statistical software R. Topics include data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions.

**Prerequisites / notice**
Basic knowledge of R equivalent to "Using R... (Part I)" (= 401-6215-00L) is a prerequisite for this course.

**Objective**
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options;
- Extending basic R: packages

**Content**
The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www rstudio.org

**Lecture notes**
An Introduction to R. [http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf](http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf)

**Prerequisites / notice**
Basic knowledge of R equivalent to "Using R... (Part I)" (= 401-6215-00L) is a prerequisite for this course.

### 401-4636-00L Data Analytics in Organisations and Business

**Abstract**
On the end-to-end data analytics process in organizations & businesses and how to transform data into insights for fact-based decisions. Presentation of the process from the beginning with framing the business problem to presenting the results and making decisions using data analytics. For each topic, case studies from the financial service, healthcare, and retail sectors will be given.

**Objective**
This course aims to give the students an understanding of the data analytics process in the business world, with a particular focus on the skills and techniques used by the business professionals. The student will become familiar with the "business language," current problems, and thinking in organizations and business and tools used.

**Content**
- Framing the Business Problem
- Framing the Analytics Problem
- Data Methodology
- Model Building
- Deployment
- Model Lifecycle
- Soft Skills for the Statistical/Mathematical Professional

**Lecture notes**
The lecture's presentation slides will be provided.

**Prerequisites / notice**
Prerequisites: Basic statistics and probability theory and regression

### 401-5199-00L Smoothing and Nonparametric Regression with Examples

**Abstract**
Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic theory, optimal bandwidth selection, data driven algorithms and some special topics. Examples from environmental research will be used for motivation, but the methods will also be applicable elsewhere.

**Objective**
- Parametric estimation methods: selection of important results
- Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
- Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
- Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.

**Content**
Rough Outline:
- Parametric estimation methods: selection of important results
  - Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
  - Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
  - Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.

**Lecture notes**
Brief summaries or outlines of some of the lecture material will be posted at [https://www.wsl.ch/en/employees/ghosh.html](https://www.wsl.ch/en/employees/ghosh.html).

**Prerequisites / notice**
Familiarity with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

**Literature**
### Prerequisites

Prerequisites: A background in Linear Algebra, Calculus, Probability & Statistical Inference including Estimation and Testing.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Type</th>
<th>Credits</th>
<th>ECTS</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>447-6221-00L</td>
<td>Nonparametric Regression</td>
<td>W</td>
<td>1</td>
<td>1G</td>
<td>M. Mächler</td>
</tr>
<tr>
<td></td>
<td>Does not take place this semester. Special Students &quot;University of Zurich (UZH)&quot; in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to <a href="mailto:registrar@ethz.ch">registrar@ethz.ch</a>. The Registrar's Office will then register you for the course.</td>
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<tr>
<td>Abstract</td>
<td>This course focusses on nonparametric estimation of probability densities and regression functions. These recent methods allow modelling without restrictive assumptions such as 'linear function'. These smoothing methods require a weight function and a smoothing parameter. Focus is on one dimension, higher dimensions and samples of curves are treated briefly. Exercises at the computer.</td>
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<tr>
<td>Objective</td>
<td>Knowledge on estimation of probability densities and regression functions via various statistical methods. Practical application on data sets at the computer.</td>
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</tbody>
</table>

| 447-6233-00L| Spatial Statistics | W    | 1       | 1G   | M. Mächler |
|             | Does not take place this semester. Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course. |
| Abstract    | In many research fields, spatially referenced data are collected. When analysing such data the focus is either on exploring their structure (dependence on explanatory variables, autocorrelation) and/or on spatial prediction. The course provides an introduction to geostatistical methods that are useful for such purposes. |
| Objective   | The course will provide an overview of the basic concepts and stochastic models that are commonly used to model geostatistical data sets. In addition, the participants will learn a number of geostatistical techniques and acquire some familiarity with software that is useful for analysing spatial data. |
| Content     | After an introductory discussion of the types of problems and the kind of data that arise in environmental research, an introduction into linear geostatistics (models: stationary random processes, modelling large-scale spatial patterns by regression, modelling autocorrelation by variogram; kriging; mean-square prediction of spatial data) will be taught. The lectures will be complemented by data analyses that the participants have to do themselves. |
| Lecture notes | Slides, descriptions of the problems for the data analyses and worked-out solutions to them will be provided. |

| 447-6245-00L| Data Mining | W    | 1       | 1G   | M. Mächler |
|             | Does not take place this semester. Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course. |
| Abstract    | Block course only on prediction problems, aka "supervised learning". Part 1, Classification: logistic regression, linear/quadratic discriminant analysis, Bayes classifier; additive and tree models; further flexible ("nonparametric") methods. Part 2, Flexible Prediction: additive models, MARS, Y-Transformation models (ACE,AVAS); Projection Pursuit Regression (PPR), neural nets. |
Content

"Data Mining" is a large field from which in this block course, we only treat so called prediction problems, aka "supervised learning".

Part 1, Classification, recalls logistic regression and linear / quadratic discriminant analysis (LDA/QDA) and extends these (in the framework of "Bayes classifier") to (generalized) additive (GAM) and tree models (CART), and further mentions other flexible ("nonparametric") methods.

Part 2, Flexible Prediction (of continuous or "class" response/target) contains additive models, MARS, Y-Transformation models (ACE, AVAS); Projection Pursuit Regression (PPR), neural nets.

Lecture notes

The block course is based on (German language) lecture notes.

Prerequisites / notice

The exercises are done exclusively with the (free, open source) software "R" (http://www.r-project.org). A final exam will also happen at the computers, using R (and your brains!).

447-6257-00L Repeated Measures ■ W 1 credit 1G

Abstract

Generation and structure of repeated measures. Planning and realization of corresponding studies. Within- and between-subjects factors.

Objective

Participants will gain the ability of recognizing repeated measures and to analyze them adequately. They will know how to deal with pseudoreplicates.

447-6191-00L Statistical Analysis of Financial Data ■ W 2 credits 1G

Abstract


Objective

Getting to know the typical properties of financial data and appropriate statistical models, incl. the corresponding functions in R.

447-6289-00L Sampling Surveys ■ W 2 credits 1G

Abstract

The elements of a sample survey are explained. The most important classical sample designs (simple random sampling and stratified random sampling) with their estimation procedures and the use of auxiliary information including the Horvitz-Thompson estimator are introduced. Data preparation, non-response and its treatment, variance estimation and analysis of survey data is discussed.

Objective

Knowledge of the Elements and the process of a sample survey. Understanding the paradigm of random samples. Knowledge of simple random sampling and stratified random sampling and capability to apply the corresponding methods. Knowledge of further methods of sampling and estimation as well as data preparation and analysis.

Lecture notes

Introduction to the statistical methods of survey research

401-3628-14L Bayesian Statistics W 4 credits 2V F. Sigrist

Abstract

Introduction to the Bayesian approach to statistics: decision theory, prior distributions, hierarchical Bayes models, empirical Bayes, Bayesian tests and model selection, empirical Bayes, Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods.

Objective

Students understand the conceptual ideas behind Bayesian statistics and are familiar with common techniques used in Bayesian data analysis.

Content

Topics that we will discuss are:

- Difference between the frequentist and Bayesian approach (decision theory, principles), priors (conjugate priors, noninformative priors, Jeffreys prior), tests and model selection (Bayes factors, hyper-g priors for regression), hierarchical models and empirical Bayes methods, computational methods (Laplace approximation, Monte Carlo and Markov chain Monte Carlo methods).

Lecture notes

A script will be available in English.

Literature


Prerequisites / notice

Familiarity with basic concepts of frequentist statistics and with basic concepts of probability theory (random variables, joint and conditional distributions, laws of large numbers and central limit theorem) will be assumed.

447-6273-00L Bayes Methods ■ W 2 credits 2G
Mathematical Foundations for Finance

Abstract
conditional probability; bayes inference (conjugate distributions, HPD-areas; linear and empirical bayes); determination of the a-posteriori distribution through simulation (MCMC with R2Winbugs); introduction to multilevel/hierarchical models.

Content
Bayes statistics is attractive, because it allows to make decisions under uncertainty where a classical frequentist statistical approach fails. The course provides an introduction into bayesian methods. It is moderately mathematically technical, but demands a flexibility of mind, which should not be underestimated.

Literature

Prerequisites / notice
Prerequisite:Basic knowledge of statistics; Knowledge of R.

Linear & Combinatorial Optimization

Abstract
Mathematical treatment of optimization techniques for linear and combinatorial optimization problems.

Objective
The goal of this course is to get a thorough understanding of various classical mathematical optimization techniques for linear and combinatorial optimization problems, with an emphasis on polyhedral approaches. In particular, we want students to develop a good understanding of some important problem classes in the field, of structural mathematical results linked to these problems, and of solution approaches based on such structural insights.

Content
Key topics include:
- Linear programming and polyhedra;
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Literature
- Equivalence between optimization and separation.
- Flows and cuts;
- Combinatorial optimization problems and polyhedral techniques;
- Equivalence between optimization and separation.

Prerequisites / notice
Solid background in linear algebra.

Mathematics of Data Science

Abstract
Mostly self-contained, but fast-paced, introductory masters level course on various theoretical aspects of algorithms that aim to extract information from data.

Objective
Introduction to various mathematical aspects of Data Science.
The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can understand and write proofs.

We encourage students who are interested in mathematical data science to take both this course and "227-0434-10L Mathematics of Information" taught by Prof. H. Bölcskei. The two courses are designed to be complementary.

A. Bandeira and H. Bölcskei

**252-0535-00L Advanced Machine Learning**

**Abstract**

Machine learning algorithms provide analytical methods to search data sets for characteristic patterns. Typical tasks include the classification of data, function fitting and clustering, with applications in image and speech analysis, bioinformatics and exploratory data analysis. This course is accompanied by practical machine learning projects.

**Objective**

Students will be familiarized with advanced concepts and algorithms for supervised and unsupervised learning; reinforce the statistics knowledge which is indispensable to solving modeling problems under uncertainty. Key concepts are the generalization ability of algorithms and systematic approaches to modeling and regularization. Machine learning projects will provide an opportunity to test the machine learning algorithms on real world data.

**Content**

The theory of fundamental machine learning concepts is presented in the lecture, and illustrated with relevant applications. Students can deepen their understanding by solving both pen-and-paper and programming exercises, where they implement and apply famous algorithms to real-world data.

Topics covered in the lecture include:

- Fundamentals: What is data?
- Bayesian Learning
- Computational learning theory
- Supervised learning: Ensembles, Bagging and Boosting
- Max Margin methods
- Neural networks
- Unsupervised learning: Dimensionality reduction techniques
- Clustering
- Mixture Models
- Non-parametric density estimation
- Learning Dynamical Systems

**Lecture notes**

No lecture notes, but slides will be made available on the course webpage.

**Literature**


**Prerequisites / notice**

The course requires solid basic knowledge in analysis, statistics and numerical methods for CSE as well as practical programming experience for solving assignments.

Students should have followed at least "Introduction to Machine Learning" or an equivalent course offered by another institution.

PhD students are required to obtain a passing grade in the course (4.0 or higher based on project and exam) to gain credit points.

**252-3005-00L Natural Language Processing**

**Abstract**

This course presents topics in natural language processing with an emphasis on modern techniques, primarily focusing on statistical and deep learning approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Objective**

The objective of the course is to learn the basic concepts in the statistical processing of natural languages. The course will be project-oriented so that the students can also gain hands-on experience with state-of-the-art tools and techniques.

**Content**

This course presents an introduction to general topics and techniques used in natural language processing today, primarily focusing on statistical approaches. The course provides an overview of the primary areas of research in language processing as well as a detailed exploration of the models and techniques used both in research and in commercial natural language systems.

**Literature**

Lectures will make use of textbooks such as the one by Jurafsky and Martin where appropriate, but will also make use of original research and survey papers.

**227-0423-00L Neural Network Theory**

**Abstract**

The class focuses on fundamental mathematical aspects of neural networks with an emphasis on deep networks: Universal approximation theorems, capacity of separating surfaces, generalization, fundamental limits of deep neural network learning, VC dimension.

**Objective**

After attending this lecture, participating in the exercise sessions, and working on the homework problem sets, students will have acquired a working knowledge of the mathematical foundations of neural networks.
Content

1. Universal approximation with single- and multi-layer networks
2. Introduction to approximation theory: Fundamental limits on compressibility of signal classes, Kolmogorov epsilon-entropy of signal classes, non-linear approximation theory
3. Fundamental limits of deep neural network learning
4. Geometry of decision surfaces
5. Separating capacity of nonlinear decision surfaces
6. Vapnik-Chervonenkis (VC) dimension
7. VC dimension of neural networks
8. Generalization error in neural network learning

Lecture notes

Detailed lecture notes are available on the course web page https://www.mins.ee.ethz.ch/teaching/nnt/

Prerequisites / notice

This course is aimed at students with a strong mathematical background in general, and in linear algebra, analysis, and probability theory in particular.

401-6282-00L Statistical Analysis of High-Throughput Genomic and Transcriptomic Data (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: STA426

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

A range of topics will be covered, including basic molecular biology, genomics technologies and in particular, a wide range of statistical and computational methods that have been used in the analysis of DNA microarray and high throughput sequencing experiments.

Objective

- Understand the fundamental "scientific process" in the field of Statistical Bioinformatics
- Be equipped with the skills/tools to preprocess genomic data (Unix, Bioconductor, mapping, etc.) and ensure reproducible research (Sweave)
- Have a general knowledge of the types of data and biological applications encountered with microarray and sequencing data
- Have the general knowledge of the range of statistical methods that get used with microarray and sequencing data
- Gain the ability to apply statistical methods/knowledge/software to a collaborative biological project
- Gain the ability to critical assess the statistical bioinformatics literature
- Write a coherent summary of a bioinformatics problem and its solution in statistical terms

Content

Lectures will include: microarray preprocessing; normalization; exploratory data analysis techniques such as clustering, PCA and multidimensional scaling; Controlling error rates of statistical tests (FPR versus FDR versus FWER); limma (linear models for microarray analysis); mapping algorithms (for RNA/ChIP-seq); RNA-seq quantification; statistical analyses for differential count data; isoform switching; epigenomics data including DNA methylation; gene set analyses; classification

Lecture notes

Lecture notes, published manuscripts

Prerequisites / notice

Prerequisites: Basic knowledge of the programming language R, sufficient knowledge in statistics

Former course title: Statistical Methods for the Analysis of Microarray and Short-Read Sequencing Data

401-8625-00L Clinical Biostatistics (University of Zurich)

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: STA404

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

Discussion of the different statistical methods that are used in clinical research.

Content

Discussion of the different statistical methods that are used in clinical research. Among other subjects the following will be introduced: sample size calculation, randomization and blinding, analysis of clinical trials (parallel groups design, analysis of covariance, crossover design, equivalence studies), intention-to-treat analysis, multiple testing, group sequential methods, adaptive designs, diagnostic studies, and agreement studies.

Literature


Prerequisites / notice

Basic knowledge of the programming language R, sufficient knowledge in calculus, linear algebra, probability, statistics

447-6201-00L Nonparametric and Resampling Methods

Special Students "University of Zurich (UZH)" in the Master Program in Biostatistics at UZH cannot register for this course unit electronically. Forward the lecturer's written permission to attend to the Registrar's Office. Alternatively, the lecturer may also send an email directly to registrar@ethz.ch. The Registrar's Office will then register you for the course.

W 2 credits 4G L. Meier, D. Kuonen

No enrolment to this course at ETH Zurich. Book the corresponding module directly at UZH as an incoming student.

UZH Module Code: STA404

Mind the enrolment deadlines at UZH: https://www.uzh.ch/cmsssl/en/studies/application/deadlines.html

Abstract

Discussion of the different statistical methods that are used in clinical research.

Content

Discussion of the different statistical methods that are used in clinical research. Among other subjects the following will be introduced: sample size calculation, randomization and blinding, analysis of clinical trials (parallel groups design, analysis of covariance, crossover design, equivalence studies), intention-to-treat analysis, multiple testing, group sequential methods, adaptive designs, diagnostic studies, and agreement studies.

Literature


Prerequisites / notice

Basic knowledge of the programming language R, sufficient knowledge in calculus, linear algebra, probability, statistics

W 2 credits 4G L. Meier, D. Kuonen
### Statistical Mathematical Courses: not eligible for credits

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-6215-00L</td>
<td>Using R for Data Analysis and Graphics (Part I)</td>
<td>E-</td>
<td>1.5</td>
<td>1G</td>
<td>M. Mächler</td>
</tr>
</tbody>
</table>

**Abstract**
The course provides the first part an introduction to the statistical software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.

**Objective**
The students will be able to use the software R for simple data analysis and graphics.

**Content**
Nonparametric tests, randomization tests, jackknife and bootstrap, as well as asymptotic properties of estimators.

**Prerequisites / notice**
This course is part of the programme for the certificate and diploma in Advanced Studies in Applied Statistics. It is given every second year in the winter semester break.

### Application Areas

Students select one area of application and look for suitable courses in which quantitative methods and modeling play a role. They need the consent by the Advisor (http://stat.ethz.ch/~kalisch/) that the chosen courses are eligible in the category “Application Areas”.

For the category assignment of eligible courses keep the choice “no category” and take contact with the Study Administration Office (www.math.ethz.ch/studiensekretariat/staff/ekuenti) after having received the credits. The Study Administration Office needs the Advisor’s consent.

### Seminar or Semester Paper

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3620-20L</td>
<td>Student Seminar in Statistics: Inference in Some Non-</td>
<td>W</td>
<td>4</td>
<td>2S</td>
<td>F. Balabdaoui</td>
</tr>
<tr>
<td></td>
<td>Standard Regression Problems</td>
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</tr>
</tbody>
</table>

**Abstract**
Review of some non-standard regression models and the statistical properties of estimation methods in such models.

**Objective**
The main goal is the students get to discover some less known regression models which either generalize the well-known linear model (for example monotone regression) or violate some of the most fundamental assumptions (as in shuffled or unlinked regression models).

**Content**
Linear regression is one of the most used models for prediction and hence one of the most understood in statistical literature. However, linearity might be too simplistic to capture the actual relationship between some response and given covariates. Also, there are many real data problems where linearity is plausible but the actual pairing between the observed covariates and responses is completely lost or at partially. In this seminar, we review some of the non-classical regression models and the statistical properties of the estimation methods considered by well-known statisticians and machine learners. This will encompass:

1. Monotone regression
2. Single index model
3. Unlinked regression

The seminar will cover a number of recent papers which have emerged as important contributions to the pattern recognition and machine learning literature. The papers will be presented in the first session of the seminar. Semester papers serve to delve into a problem in statistics and to study it with the appropriate methods or to compile and clearly exhibit a case study of a statistical evaluation. Possible topics cover statistical models in computer vision, graphical models and machine learning. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from seminal papers on machine learning literature. The topics will vary from year to year but they are centered on methodological issues in machine learning like new learning algorithms, ensemble methods or new statistical models for machine learning applications. Frequently, papers are selected from seminal papers on machine learning literature.

The students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

Prerequisites / notice
The students need to be comfortable with regression models, classical estimation methods (Least squares, Maximum Likelihood estimation...), rates of convergence, asymptotic normality, etc.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Prerequisites</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-3630-04L</td>
<td>Semester Paper</td>
<td>4 credits</td>
<td>6A Supervisors</td>
<td>literature entries</td>
</tr>
<tr>
<td>401-3630-06L</td>
<td>Semester Paper</td>
<td>6 credits</td>
<td>9A Supervisors</td>
<td>literature entries</td>
</tr>
<tr>
<td>252-5051-00L</td>
<td>Advanced Topics in Machine Learning</td>
<td>2 credits</td>
<td>2S</td>
<td>J. M. Buhmann, R. Cotterell, J. Vogt, F. Yang</td>
</tr>
</tbody>
</table>

**GESS Science in Perspective**

Two credits are needed from the "Science in Perspective" programme with language courses excluded if three credits from language courses have already been recognised for the Bachelor's degree. See https://ethz.ch/content/dam/ethz/common/docs/weisungssammlung/files-en/science-in-perspective.pdf (Eight credits must be acquired in this category: normally six during the Bachelor's degree programme, and two during the Master's degree programme. A maximum of three credits from language courses from the range of the Language Center of the University of Zurich and ETH Zurich may be recognised. In addition, only advanced courses (level B2 upwards) in the European languages English, French, Italian and Spanish are recognised. German language courses are recognised from level C2 upwards.)

see GESS Science in Perspective: Language Courses
ETH/UZH

see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MATH.
Master's Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>401-2000-00L</td>
<td>Scientific Works in Mathematics</td>
<td>O</td>
<td>0</td>
<td></td>
<td>M. Burger</td>
</tr>
<tr>
<td></td>
<td>Target audience:</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Third year Bachelor students; Master students who cannot to have received an adequate training in working scientifically.</td>
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</tr>
<tr>
<td>Abstract</td>
<td>Introduction to scientific writing for students with focus on publication standards and ethical issues, especially in the case of citations (references to works of others).</td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Learn the basic standards of scientific works in mathematics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>- Types of mathematical works</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>- Publication standards in pure and applied mathematics</td>
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<tr>
<td></td>
<td>- Data handling</td>
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<tr>
<td></td>
<td>- Ethical issues</td>
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<tr>
<td></td>
<td>- Citation guidelines</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-2000-01L</td>
<td>Lunch Sessions – Thesis Basics for Mathematics Students</td>
<td>Z</td>
<td>0</td>
<td></td>
<td>Speakers</td>
</tr>
<tr>
<td>Abstract</td>
<td>Optional MathBib training course</td>
<td></td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>401-4990-02L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30</td>
<td>57D</td>
<td>Supervisors</td>
</tr>
<tr>
<td></td>
<td>Only students who fulfill the following criteria are allowed to begin with their Master's thesis:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>a. successful completion of the Bachelor's programme;</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>b. fulfilling of any additional requirements necessary to gain admission to the Master's programme;</td>
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</tr>
<tr>
<td></td>
<td>c. They have acquired at least 16 credits in the category “Core courses” for Programme Regulations 2014 and 40 credits in the category “Main Areas” for Programme Regulations 2020.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td>The master's thesis concludes the study programme. Thesis work should prove the students' ability to independent, structured and scientific working.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Thesis work should prove the students' ability to independent, structured and scientific working.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Content</td>
<td>Five-month project to solve a research question. The content can be more theoretical (e.g. proving a new result) or applied (developing new methods or making a very sophisticated application and adapting existing methods).</td>
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<td></td>
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</tr>
<tr>
<td>Prerequisites / notice</td>
<td>Supervisors are chosen on a first-come-first-served basis. Collaborations with industry are possible.</td>
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</tr>
</tbody>
</table>

Course Units for Additional Admission Requirements

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0173-AAL</td>
<td>Linear Algebra I and II</td>
<td>E</td>
<td>6</td>
<td>13R</td>
<td>N. Hungerbühler</td>
</tr>
</tbody>
</table>

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Linear algebra is an indispensable tool of engineering mathematics. The course is an introduction to basic methods and fundamental concepts of linear algebra and its applications to engineering sciences.

Objective

After completion of this course, students are able to recognize linear structures and to apply adequate tools from linear algebra in order to solve corresponding problems from theory and applications. In addition, students have a basic knowledge of the software package Matlab.

Content


Linear maps, kernel and image, coordinates and matrices, coordinate transformations, norm of a matrix, orthogonal matrices, eigenvalues and eigenvectors, algebraic and geometric multiplicity, eigenbasis, diagonalizable matrices, symmetric matrices, orthonormal basis, condition number, linear differential equations, Jordan decomposition, singular value decomposition, examples in MATLAB, applications.

Reading:

Gilbert Strang "Introduction to linear algebra", Wellesley-Cambridge Press: Chapters 1-6, 7.1-7.3, 8.1, 8.2, 8.6


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>406-0243-AAL</td>
<td>Analysis I and II</td>
<td>E</td>
<td>14</td>
<td>30R</td>
<td>M. Akveld</td>
</tr>
</tbody>
</table>

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
### 406-0503-AAL Stochastics (Probability and Statistics)

<table>
<thead>
<tr>
<th>Title</th>
<th>E-</th>
<th>Credits</th>
<th>R</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stochastics (Probability and Statistics)</td>
<td>4</td>
<td>0</td>
<td>M. Kalisch</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

**Objective**

Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

**Content**

From "Statistics for research" (online)
- Ch 1: The Role of Statistics
- Ch 2: Populations, Samples, and Probability Distributions
- Ch 3: Binomial Distributions
- Ch 6: Sampling Distribution of Averages
- Ch 7: Normal Distributions
- Ch 8: Student's t Distribution
- Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
- Ch 1: Basics
- Ch 2: The R Environment
- Ch 3: Probability and distributions
- Ch 4: Descriptive statistics and tables
- Ch 5: One- and two-sample tests
- Ch 6: Regression and correlation

**Literature**

- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
- From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435
- From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

### 406-2604-AAL Probability and Statistics

<table>
<thead>
<tr>
<th>Title</th>
<th>E-</th>
<th>Credits</th>
<th>R</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability and Statistics</td>
<td>7</td>
<td>15</td>
<td>J. Teichmann</td>
<td></td>
</tr>
</tbody>
</table>

**Abstract**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

**Objective**

The goal of this course is to provide an introduction to the basic ideas and concepts from probability theory and mathematical statistics. In addition to a mathematically rigorous treatment, also an intuitive understanding and familiarity with the ideas behind the definitions are emphasized. Measure theory is not used systematically, but it should become clear why and where measure theory is needed.

**Content**

**Probability**
- Chapters 1-5 (Probabilities and events, Discrete and continuous random variables, Generating functions) and Sections 7.1-7.5 (Convergence of random variables) from the book "Probability and Random Processes". Most of this material is also covered in Chap. 1-5 of "Mathematical Statistics and Data Analysis", on a slightly easier level.

**Statistics**
- Sections 8.1 - 8.5 (Estimation of parameters), 9.1 - 9.4 (Testing Hypotheses), 11.1 - 11.3 (Comparing two samples) from "Mathematical Statistics and Data Analysis".

**Literature**

**Statistics Master - Key for Type**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
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</table>

**Key for Hours**

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**

European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
Objective

More specifically upon completion of the course, you will have gained insight into:
- how to structure the large amount of information that is often associated with attempting to modify complex systems
- how to set goals and define constraints in the engineering of complex systems
- how to generate possible solutions to complex problems in ways that limit exceedingly narrow thinking
- how to compare multiple possible solutions over time with differences in the temporal distribution of costs and benefits and uncertainty as to what might happen in the future
- how to assess values of benefits to stakeholders that are not in monetary units
- how to assess whether it is worth obtaining more information in determining optimal solution
- how to take a step back from the numbers and qualitatively evaluate the possible solutions in light of the bigger picture
- the basics of operations research and how it can be used to determine optimal solutions to complex problems, including linear, integer and network programming, dealing with multiple objectives and conducting sensitivity analyses.

### Literature

- Urs Stammbach, "Analysis III" (erhältlich im ETH Store); https://people.math.ethz.ch/~stammb/analysisskript.html

### Data

- Date: 14.12.2021 12:41
- Autumn Semester 2021
- Page 1983 of 2152
The weekly lectures are structured as follows:

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. An introduction to the example that we will be working with through most of the course. The expectations of your efforts throughout the semester.
2. Situation analysis – How to structure the large amount of information that is often associated with attempting to modify complex systems.
3. Goals and constraints – How to set goals and constraints to identify the best solutions as clearly as possible.
4. Generation of possible solutions – How to generate possible solutions to problems, considering multiple stakeholders.
5. Analysis – 1/5 – The principles of net-benefit maximization and a series of methods that range from qualitative and approximate to quantitative and exact, including pairwise comparison, elimination, display, weighting, and expected value.
6. Analysis – 2/5 – The idea behind the supply and demand curves and revealed preference methods.
7. Analysis – 3/5 – The concept of equivalence, including the time value of money, interest, life times and terminal values.
8. Analysis – 4/5 – The relationship between net-benefit and the benefit-cost ratio. How incremental cost benefit analysis can be used to determine the maximum net benefit. Marginal rates of return and internal rates of return.
9. Analysis – 5/5 – How to consider multiple possible futures and use simple rules to help pick optimal solutions and to determine the value of more information.
10. Evaluation of solutions – Regardless how sophisticated an analysis is, it requires that decision makers stand back and critically evaluate the results. This week we discuss the aspects of evaluating the results of an analysis.
11. Operations research – 1/4 – Once quantitative analysis is used it becomes possible to use operations research methods to analyse large numbers of possible solutions. This week we discuss linear programming and the simplex method.
13. Operations research – 3/4 – How to use operations research to solve problems that consist of discrete values, as well as how to exploit the structure of networks to find optimal solutions to network problems.
14. Operations research – 4/4 – How to set up and solve problems when there are multiple objectives.

The course uses a combination of qualitative and quantitative approaches. The quantitative analyses requires the use of Excel. An introduction to Excel will be provided in one of the help sessions.

The lecture materials will be distributed via Moodle two days before each lecture.

### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories          | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies    | assessed |
| Domain C - Social Competencies         | Analytical Competencies         | assessed |
|                                       | Decision-making                | assessed |
|                                       | Media and Digital Technologies | not assessed |
|                                       | Problem-solving                | assessed |
|                                       | Project Management             | not assessed |
| Domain D - Personal Competencies       | Communication                  | not assessed |
|                                       | Cooperation and Teamwork       | not assessed |
|                                       | Customer Orientation           | not assessed |
|                                       | Leadership and Responsibility  | not assessed |
|                                       | Self-presentation and Social Influence | not assessed |
|                                       | Sensitivity to Diversity       | not assessed |
|                                       | Negotiation                    | not assessed |
|                                       | Adaptability and Flexibility   | not assessed |
|                                       | Creative Thinking              | not assessed |
|                                       | Critical Thinking              | assessed  |
|                                       | Integrity and Work Ethics      | not assessed |
|                                       | Self-awareness and Self-reflection | not assessed |
|                                       | Self-direction and Self-management | not assessed |

### Literature

The course is based on Press & Siever book Dynamic Earth by Grotzinger et al., available to ETH students via https://link.springer.com/book/10.1007/978-3-662-48342-8

The course requires no prerequisites.

### Prerequisites / notice

Autumn Semester 2021

**Content**

1. Introduction – An introduction to System Engineering, a way of thinking that helps to engineer sustainable systems, i.e. ones that meet the needs of stakeholders in the short, medium and long terms. A high-level overview of the main principles of System Engineering. An introduction to the example that we will be working with through most of the course. The expectations of your efforts throughout the semester.
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### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories          | assessed |
| Domain B - Method-specific Competencies | Techniques and Technologies    | assessed |
| Domain C - Social Competencies         | Analytical Competencies         | assessed |
|                                       | Decision-making                | assessed |
|                                       | Media and Digital Technologies | not assessed |
|                                       | Problem-solving                | assessed |
|                                       | Project Management             | not assessed |
| Domain D - Personal Competencies       | Communication                  | not assessed |
|                                       | Cooperation and Teamwork       | not assessed |
|                                       | Customer Orientation           | not assessed |
|                                       | Leadership and Responsibility  | not assessed |
|                                       | Self-presentation and Social Influence | not assessed |
|                                       | Sensitivity to Diversity       | not assessed |
|                                       | Negotiation                    | not assessed |
|                                       | Adaptability and Flexibility   | not assessed |
|                                       | Creative Thinking              | not assessed |
|                                       | Critical Thinking              | assessed  |
|                                       | Integrity and Work Ethics      | not assessed |
|                                       | Self-awareness and Self-reflection | not assessed |
|                                       | Self-direction and Self-management | not assessed |

### Literature

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The course requires no prerequisites.

### Prerequisites / notice

Autumn Semester 2021

**Content**

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The lecture materials will be distributed via Moodle two days before each lecture.
1. Stoichiometry
Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
Elementary particles and atoms. Electron configuration of the elements. Periodic system.
4. Basics of chemical thermodynamics
System and surroundings. Description of state and change of state of chemical systems.
5. First law of thermodynamics
6. Second law of thermodynamics
Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
8. Chemical equilibrium
Law of mass action. Reaction quotient and equilibrium constant. Phase transition equilibrium.
9. Acids and bases
10. Dissolution and precipitation.
Heterogeneous equilibrium. Dissolution and solubility product. Carbon dioxide-carbonic acid-carbonate equilibrium.

Lecture notes
Online-Skript mit durchgerechneten Beispielen.

Literature
Weiterführende Literatur:

3. Semester

Compulsory Courses 3. Semester

Examination Block 1

Number Title Type ECTS Hours Lecturers
402-0023-01L Physics O 7 credits 5V+2U S. Johnson

Abstract
This course gives an overview of important concepts in classical dynamics, thermodynamics, electromagnetism, quantum physics, atomic physics, and special relativity. Emphasis is placed on demonstrating key phenomena using experiments, and in developing skills for quantitative problem solving.

Objective
The goal of this course is to make students able to explain and apply the basic principles and methodology of physics to problems of interest in modern science and engineering. An important component of this is learning how to solve new, complex problems by breaking them down into parts and applying simplifications. A secondary goal is to provide to students an overview of important subjects in both classical and modern physics.

Content
Electrodynamics, Thermodynamics, Quantum physics, Waves and Oscillations, special relativity

Lecture notes
Lecture notes and exercise sheets will be distributed via Moodle

Literature
The course introduces the students to engineering hydrology. It covers first physical hydrology, that is the description and the measurement of properties of water, hydrostatics, stability of floating bodies, continuity, Euler equation of motion, Navier-Stokes equations, similarity, and the hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.

**Domain A - Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Domain C - Social Competencies**
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Domain D - Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

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**Hydraulics I**

**Objective**
Familiarization with the basics of hydromechanics of steady state flows

**Content**
- Bernoulli principle, momentum equation for finite volumes, potential flows, ideal fluids vs. real fluids, boundary layer, pipe flow, open channel flow, flow measurements, demonstration experiments in the lecture hall

**Lecture notes**
Script and collection of previous problems

**Literature**
Bollrich, Technische Hydromechanik 1, Verlag Bauwesen, Berlin

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**GIS I for Environmental Engineers**

**Objective**
Knowing the fundamentals of geoinformation technologies for the realization, application and operation of geographic information systems in engineering projects.

**Content**
- Einführung GIS & GIScience
- Konzeptionelles Modell & Datenschema
- Vektorgeometrie & Topologie
- Rastergeometrie und -algebra
- Thematische Daten
- Räumliche Abfragen & Analysen
- Geodatenbanken

**Lecture notes**
Vorlesungspräsentationen werden digital zur Verfügung gestellt.

**Literature**

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**Hydrology**

**Objective**
The course introduces the students to engineering hydrology. It covers first physical hydrology, that is the description and the measurement of hydrological processes (precipitation, interception, evapotranspiration, runoff, erosion, and snow), and it introduces then the basic mathematical models of the single processes and of the rainfall-runoff transformation, thereby including flood analysis.

**Content**
- The main features of engineering hydrology. Apply methods to estimate hydrological variables for dimensioning hydraulic structures and managing water resources.
- The hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.
- Precipitation: mechanisms of precipitation formation, precipitation measurements, variability of precipitation in space and time, precipitation regimes, point/basin precipitation, isohyetal method, Thiessen polygons, storm rainfall, design hyetograph.
- Interception: measurement and estimation.
- Evaporation and evapotranspiration: processes, measurement and estimation, potential and actual evapotranspiration, energy balance method, empirical methods.
- Infiltration: measurement, Horton’s equation, empirical and conceptual models, phi-index and percentage method, SCS-CN method.
- Surface runoff and subsurface flow: Hortonian and Dunnian surface runoff, streamflow measurement, streamflow regimes, annual hydrograph, flood hydrograph analysis – baseflow separation, flow duration curve.
- Basin characteristics: morphology, topographic and phreatic divide, hypsometric curve, slope, drainage density.
- Rainfall-runoff models (R-R): rationale, linear model of rainfall-runoff transformation, concept of the instantaneous unit hydrograph (IUH), linear reservoir, Nash model.
- Flood estimation methods: flood frequency analysis, deterministic methods, probabilistic methods (e.g. statistical regionalisation, indirect R-R methods for flood estimation, rational method).
- Erosion and sediment transport: watershed scale erosion, soil erosion by water, estimation of surface erosion, sediment transport.

**Lecture notes**
The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.

**701-0243-01L Biology III: Essentials of Ecology**

<table>
<thead>
<tr>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>C. Buser Moser</td>
</tr>
</tbody>
</table>

Abstract

This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified by using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. Threats to biodiversity and the appropriate management are discussed.

Objective

The objective of this lecture is to teach basic ecological concepts and the different levels of complexity in ecological research. The students should learn ecological concepts at these different levels in the context of concrete examples from terrestrial and aquatic ecology. Corresponding methods for studying the systems will be presented. A further aim of the lecture is that students achieve an understanding of biodiversity, why it is threatened and how it can be managed.

Content

- Einfluss von Umweltfaktoren (Temperatur, Strahlung, Wasser, Nährstoffe etc.) auf Organismen; Anpassung an bestimmte Umweltbedingungen
- Populationsdynamik: Ursachen, Beschreibung, Vorhersage und Regulation
- Interaktionen zwischen Arten (Konkurrenz, Koexistenz, Prädation, Parasitismus, Nahrungsnetze)
- Lebensgemeinschaften: Struktur, Stabilität, Sukzession
- Ökosysteme: Kompartimente, Stoff- und Energieflusse
- Biodiversität: Variation, Ursachen, Gefährdung und Erhaltung
- Aktuelle Naturschutzprobleme und -massnahmen
- Evolutionäre Ökologie: Methodik, Spezialisierung, Koevolution

Lecture notes

Unterlagen, Vorlesungsskript und relevante Literatur sind in Moodle abrufbar. Die Unterlagen für die nächste Vorlesung stehen jeweils spätestens am Freitagmorgen zur Verfügung.

Literature

Generelle Ökologie:

- Bohle 1995. Limnische Systeme. Springer, ca. Fr. 50.-

Naturschutzökologie:


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### Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Lecturers</th>
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<tr>
<td>752-4001-00L</td>
<td>Microbiology</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>M. Ackermann, M. Schuppler, J. Vorholt-Zambelli</td>
</tr>
<tr>
<td>752-0100-00L</td>
<td>Biochemistry</td>
<td>O</td>
<td>2</td>
<td>2V</td>
<td>C. Frei</td>
</tr>
</tbody>
</table>

### Microbiology

Abstract

Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective

Teaching of basic knowledge in microbiology.

Content


Lecture notes

Wird von den jeweiligen Dozenten ausgegeben.

Literature

Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms.

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### Biochemistry

Abstract

Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

Objective

Students are able to understand

- the structure and function of biological macromolecules
- the kinetic bases of enzyme reactions
- thermodynamic and mechanistic basics of relevant metabolic processes

Students are able to describe the relevant metabolic reactions in detail

Content

Program

Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry Structure and function of proteins Carbohydrates Lipids an biological membranes Enzymes and enzyme kinetics Catalytic strategies Metabolism: Basic concepts and design. Repetition of basic thermodynamics Glycolysis, fermentation The citric acid cycle Oxidative phosphorylation Fatty acid metabolism

Lecture notes

Horton et al. (Pearson) serves as lecture notes.

Prerequisites / notice

Basic knowledge in biology and chemistry is a prerequisite.
Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies

- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

Domain C - Social Competencies

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies

- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

Domain A - Subject-specific Competencies

- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies

- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed

Domain C - Social Competencies

- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies

- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

5. Semester

Compulsory Courses 5. Semester

Examination Block 3

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
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<th>Lecturers</th>
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<tr>
<td>102-0215-00L</td>
<td>Urban Water Management II</td>
<td>O</td>
<td>4</td>
<td>2G</td>
<td>M. Maurer, P. Staufer</td>
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<tr>
<td>Objective</td>
<td>Consolidation of the basic procedures for design and operation of technical networks in water engineering.</td>
<td></td>
<td></td>
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<td>Lecture notes</td>
<td>Written material will be available digital.</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisite: Introduction to Urban Water Management</td>
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<td>Taught competencies</td>
<td>Domain A - Subject-specific Competencies Concepts and Theories Techniques and Technologies</td>
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<tr>
<td>Domain B - Method-specific Competencies Analytical Competencies Decision-making Problem-solving Project Management</td>
<td>assessed</td>
<td>assessed</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies Cooperation and Teamwork</td>
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<tr>
<td>Domain D - Personal Competencies Adaptability and Flexibility</td>
<td>not assessed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

102-0455-01L | Groundwater I | O | 4 | 3G | J. Jimenez-Martinez, M. Willmann |
| Abstract | The course provides a quantitative introduction to groundwater flow and contaminant transport processes. Formulation and solving of practical problems. |      |      |                                 |
| Objective | Understanding of the basic concepts on groundwater flow and contaminant transport processes. Properties of porous and fractured media, Darcy’s law, flow equation, stream functions, interpretation of pumping tests, transport processes, transport equation, analytical solutions for transport, numerical methods: finite difference methods, aquifers remediation, case studies. |      |      |                                 |
| Content | Properties of porous and fractured media, Darcy’s law, flow equation, stream functions, interpretation of pumping tests, transport processes, transport equation, analytical solutions for transport, numerical methods. |      |      |                                 |
| Lecture notes | Script and collection of problems available |      |      |                                 |

102-0635-01L | Air Pollution Control | O | 6 | 4G | J. Wang, B. Buchmann |
| Abstract | The lecture provides in the first part an introduction to the formation of air pollutants by technical processes, the emission of these chemicals into the atmosphere and their impact on air quality. The second part covers different strategies and techniques for emission reduction. The basic knowledge is deepened by the discussion of specific air pollution problems of today’s society. |      |      |                                 |
| Objective | The students gain general knowledge of the technical processes resulting in air pollution and study the methods used for air pollution control. The students can identify major air pollution sources and understand the methods for measuring pollutants, collecting and analyzing data. The students can suggest and evaluate possible control methods and equipment, design control systems and estimate their efficiency and efforts. The students know the different strategies of air pollution control and are familiar with their scientific fundamentals. They are able to incorporate goals concerning air quality into their engineering work. |      |      |                                 |
Content

Part 1 Emission, Immission, Transmission
- Fluxes of pollutants and their environmental impact:
  - physical and chemical processes leading to emission of pollutants
  - mass and energy of processes
  - Emission measurement techniques and concepts
  - quantification of emissions from individual and aggregated sources
  - extent and development of the emissions (Switzerland and global)
- propagation and transport of pollutants (transmission)
- meteorological parameters influencing air pollution dispersion
- deterministic and stochastic models, describing air pollution dispersion
- dispersion models (Gaussian model, box model, receptor model)
- measurement concepts for ambient air (immission level)
- extent and development of ambient air mixing ratios
- goal and instrument of air pollution control

Part 2 Air Pollution Control Technologies
- The reduction of the formation of pollutants is done by modifying the processes (pro-cessintegrated measures) and by different engineering operations for the cleaning of waste gas (downstream pollution control). It will be demonstrated, that the variety of these procedures can be traced back to the application of a few basic physical and chemical principles.

- Procedures for the removal of particles (inertial separator, filtration, electrostatic precipitators, scrubbers) with their different mechanisms (field forces, impaction and diffusion processes) and the modelling of these mechanisms.

- Procedures for the removal of gaseous pollutants and the description of the driving forces involved, as well as the equilibrium and the kinetics of the relevant processes (absorption, adsorption as well as thermal, catalytic and biological conversions).

Discussion of the technical possibilities to solve the actual air pollution problems.

Lecture notes
Brigitte Buchmann, Air pollution control, Part I
Jing Wang, Air pollution control, Part II
Lecture slides and exercises

Literature
List of literature included in script
College lectures on basic physics, chemistry and mathematics.
Language of instruction: In German or in English.

102-0675-00L Earth Observation O 4 credits 3G I. Hainsek, E. Baltsavias

Abstract
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation.

Objective
The aim of the course is to provide the fundamental knowledge about earth observation sensors, techniques and methods for bio/geophysical environmental parameter estimation. Students should know at the end of the course:
1. Basics of measurement principle
2. Fundamentals of image acquisition
3. Basics of the sensor-specific geometries
4. Sensor-specific determination of environmental parameters

Content
Die Lehrveranstaltung gibt einen Einblick in die heutige Erdbeobachtung mit dem folgenden skizzierten Inhalt:
1. Einführung in die Fernerkundung von Luft- und Weltraum gestützten Systemen
2. Einführung in das Elektromagnetische Spektrum
3. Einführung in optische Systeme (optisch und hyperspektral)
4. Einführung in Mikrowellen-Technik (aktiv und passiv)
5. Einführung in atmosphärische Systeme (meteo und chemisch)
6. Einführung in die Techniken und Methoden zur Bestimmung von Umweltparametern
7. Einführung in die Anwendungen zur Bestimmung von Umweltparametern in der Hydrologie, Glaziologie, Forst und Landwirtschaft, Geologie und Topographie

Lecture notes
Folien zu jeden Vorlesungsblock werden zur Verfügung gestellt.

Literature
Ausgewählte Literatur wird am Anfang der Vorlesung vorgestellt.

Examination Block 4

Number Title Type ECTS Hours Lecturers
101-0031-02L Business Administration O 2 credits 2V M. Passardi, P. Barmettler

Abstract
Introduction to business administration
Principles of accounting and financial management
Financial planning and capital budgeting of projects
Costing systems by corporations

Objective
Prepare and analyze the financial statements of organizations
Establish budget and determine profitability of investment
Understand the major costing systems
Perform some product calculations

Content
Overview in business administration
Financial Accounting
- Balance sheet, income statement
- Accounts, double-entry bookkeeping
- Year-end closing and financial statements

Financial Management
- Financial statement analysis
- Financial planning
- Investment decisions

Management Accounting
- Full costing and marginal costing
- Product costing
- Management decisions

Lecture notes
Nicht vorhanden.

Literature
Nicht vorhanden.

Projects are not only the base of work in modern enterprises but also the primary type of cooperation with customers. Students of ETH will learn fundamental structures of the legal system, understand core concepts and selected problems of public law, focusing on Swiss and European environmental law. These insights can be applied in further law courses, in particular in the course "Environmental law: Areas and Case Studies."


The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project. Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

The course is organized in the form of seminars held by the students. Topics selected from the core disciplines of the curriculum (water resources, urban water engineering, material fluxes, waste technology, air polution, earth observation) are discussed in the class on the basis of scientific papers that are illustrated and critically reviewed by the students.

Learn about recent research results in environmental engineering and analyse practical applications in environmental engineering.

The students will understand the basics of noise abatement: acoustics, impact of noise, measurement techniques and legislation. The students will be able to analyze different noise prob-lems and they will be able to solve simple problems of noise abatement.
### Elective Block: Soil Protection

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0501-00L</td>
<td>Pedosphere</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Kretzschmar</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

**Objective**
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

**Content**
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil fertility, land use and soil degradation.

**Lecture notes**
Polybook

**Prerequisites / notice**
Prerequisites: Basic knowledge in chemistry, biology and geology.

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>701-0533-00L</td>
<td>Soil and Water Chemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. Kretzschmar, D. I. Christl, L. Winkel</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

**Objective**
1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, availability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

**Content**
Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

**Lecture notes**
Lecture slides on Moodle

**Literature**
--Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.

**Prerequisites / notice**
The lecture courses Pedosphere and Hydrosphere are highly recommended.

### Elective Block: Civil Engineering

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<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0339-00L</td>
<td>Environmental Geotechnics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Plötze</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction of basic knowledge about problems with contaminated sites, investigation of this sites, risk management, remediation and reclamation techniques as well as monitoring systems.
Introduction in landfill design and engineering with focus on barrier- and drainage systems and lining materials, evaluation of geotechnical problems, e.g. stability.

**Objective**
Introduction of basic knowledge about problems with contaminated sites, investigation of this sites, risk management, remediation and reclamation techniques as well as monitoring systems.
Introduction in landfill design and engineering with focus on barrier- and drainage systems as well as lining materials, evaluation of geotechnical problems, e.g. stability.

**Content**
Definition of contaminated sites, site investigation methods, historical research and technical investigation, risk assessment, contamination transport, remediation, clean-up and retaining techniques (e.g. bioremediation, incineration, retaining walls, pump-and-treat, permeable reactive barriers), monitoring, research projects and results

**Prerequisites / notice**
Prerequisites: Basic knowledge in chemistry, biology and geology.

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<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>101-0113-10L</td>
<td>Theory of Structures (for Environmental Engineering)</td>
<td>W</td>
<td>3 credits</td>
<td>2.5G</td>
<td>B. Sudret</td>
</tr>
</tbody>
</table>

**Abstract**
Introduction to structural mechanics, statically determinate beams and frame structures, trusses. Stresses in statically determinate structures.
- Understanding the response of elastic beam and frame structures
- Ability to correctly apply the equilibrium conditions
- Understanding the basics of continuum mechanics
- Computation of stresses in elastic structures
Lecture slides and supplementary documentation will be available online.


This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of the analysis of the electric power transmission and distribution grids as well as many modern technological devices – consumer electronics, control systems, computers and communications.

Bruno Sudret, "Einführung in die Baustatik" (2018)

Additional course material will be available on the web page: https://sudret.ibk.ethz.ch/education/baustatik-for-environmental-engineers.html


Elective Block: Energy

At least 10 KP must be achieved for the elective block: Energy.

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<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-1635-00L</td>
<td>Electric Circuits</td>
<td>W</td>
<td>4 credits</td>
<td>3G</td>
<td>M. Zima, D. Shchetinin</td>
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<td></td>
<td>Students without a background in Electrical Engineering must take &quot;Electric Circuits&quot; before taking &quot;Introduction to Electric Power Transmission: System &amp; Technology&quot;</td>
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<td></td>
<td>Introduction to analysis methods and network theorems to describe operation of electric circuits. Theoretical foundations are essential for the analysis of the electric power transmission and distribution grids as well as many modern technological devices – consumer electronics, control systems, computers and communications.</td>
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<td>At the end of this course, the student will be able to: understand variables in electric circuits, evaluate possible approaches and analyse simple electric circuits with RLC elements, apply circuit theorems to simple meshed circuits, analyze AC circuits in a steady state and understand the connection of the explained principles to the modelling of the 3-phase electric power systems.</td>
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<td>Course will introduce electric circuits variables, circuit elements (resistive, inductive, capacitive), resistive circuits and theorems (Kirchhoffs’ laws, Norton and Thevenin equivalents), nodal and mesh analysis, superposition principle; it will continue by discussing the complete response circuits (RLC), sinusoidal analysis – ac steady state (complex power, reactive, active power) and conclude with the introduction to 3-phase analysis; Mathematical foundations of the circuit analysis, such as matrix operations and complex numbers will be briefly reviewed.</td>
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<td>This course is targeting students who have no prior background in electrical engineering.</td>
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<td>Lecture and exercises slides will be distributed after each lecture via moodle platform; additional materials to be accessed online (wileyplus)</td>
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<tr>
<td>Literature</td>
<td>Richard C. Dorf, James A. Svoboda</td>
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<tr>
<td></td>
<td>Introduction to Electric Circuits, 9th Edition</td>
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<td>Online materials: <a href="https://www.wileyplus.com/">https://www.wileyplus.com/</a></td>
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<tr>
<td></td>
<td>Lecture slides and exercises slides</td>
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<tr>
<td>Prerequisites / notice</td>
<td>This course is intended for students outside of D-ITET. No prior course in electrical engineering is required</td>
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| 151-1633-00L | Energy Conversion                          | W    | 4 credits | 3G   | I. Karlin, G. Sansavini |
|              | This course is intended for students outside of D-MAVT. |
|              | This course provides the students with an introduction to thermodynamics and energy conversion. Students shall gain basic understanding of energy and energy interactions as well as their link to energy conversion technologies. |
|              | Thermodynamics is key to understanding and use of energy conversion processes in Nature and technology. Main objective of this course is to give a compact introduction into basics of Thermodynamics: Thermodynamic states and thermodynamic processes; Work and Heat; First and Second Laws of Thermodynamics. Students shall learn how to use energy balance equation in the analysis of power cycles and shall be able to evaluate efficiency of internal combustion engines, gas turbines and steam power plants. The course shall extensively use thermodynamic charts to building up students’ intuition about opportunities and restrictions to increase useful work output of energy conversion. Thermodynamic functions such as entropy, enthalpy and free enthalpy shall be used to understand chemical and phase equilibrium. The course also gives introduction to refrigeration cycles, combustion and refrigeration. The course compactly covers the standard course of thermodynamics for engineers, with additional topics of a general physics interest (nonideal gas equation of state and Joule-Thomson effect) also included. |
|              | 1. Thermodynamic systems, states and state variables |
|              | 2. Properties of substances: Water, air and ideal gas |
|              | 3. Energy conservation in closed and open systems: work, internal energy, heat and enthalpy |
|              | 4. Second law of thermodynamics and entropy |
|              | 5. Energy analysis of steam power cycles |
|              | 6. Energy analysis of gas power cycles |
|              | 7. Refrigeration and heat pump cycles |
|              | 8. Nonideal gas equation of state and Joule-Thomson effect |
|              | 9. Maximal work and exergy |
|              | 10. Mixtures |
|              | 11. Chemical reactions and combustion systems; chemical and phase equilibrium |
|              | Lecture slides and supplementary documentation will be available online. |
| Prerequisites / notice | This course is intended for students outside of D-MAVT. |
|              | Students are assumed to have an adequate background in calculus, physics, and engineering mechanics. |
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Electives
The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

GESS Science in Perspective
see GESS Science in Perspective: Language Courses
see GESS Science in Perspective: Type A: Enhancement of Reflection Capability
Recommended GESS Science in Perspective (Type B) for D-BAUG.

Bachelor's Thesis
Abstract
The Bachelor Programme concludes with the Bachelor Thesis. This project is supervised by a professor. Writing up the Bachelor Thesis encourages students to show independence and to produce structured work.

Objective
Encourages students to show independence, to produce scientifically structured work and to apply engineering working methods.

Content
The contents base upon the fundamentals of the Bachelor Programme. Students can choose from different subjects and tasks. The thesis consists of both a written report and an oral presentation.

Environmental Engineering Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0006-00L</td>
<td>Bachelor's Thesis</td>
<td>O</td>
<td>10 credits</td>
<td>21D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Key for Hours

| V | lecture                      | P   | practical/laboratory course |
| G | lecture with exercise        | A   | independent project         |
| U | exercise                     | D   | diploma thesis              |
| S | seminar                      | R   | revision course / private study |
| K | colloquium                   |     |                               |

ECTS
European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
Advanced Environmental, Social and Economic Assessments

The combined course unit is only for Master students in Environmental Engineering. All other students enrol for one or both out of the single courses.

Abstract
This course deepens students’ knowledge of environmental, economic, and social assessment methodologies and their various applications.

Objective
This course has the aim of deepening students’ knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors.

- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies

In the course element “Implementation of Environmental and other Sustainability Goals”, students will learn to:
- Describe key sustainability problems of the current economic system and measuring units
- Describe the management system of an organisation and how to develop a sustainability orientation
- Discuss approaches to measure environmental performance of an organisation, including ‘organisational LCA’ (Ecobalance)
- Explain the pros and cons of single score environmental assessment methods
- Demonstrate life cycle costing
- Interpret stakeholder relations of an organisation
- (If time allows) describe sustainable supply chain management and stakeholder management

Part I: Advanced Environmental Assessments

- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

Part II: Implementation of Environmental and other Sustainability Goals:

- Sustainability problems of the current economic system and its measuring units
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication
- Sustainability Opportunities and Innovation
- The concept of ‘Continuous Improvement’
- Life Cycle Costing, Life Cycle Management
- Environmental performance measurement of an organisation, including ‘organisational LCA’ (Ecobalance), based on practical examples of companies and new concepts
- Single score env. assessment methods (Swiss ecopoints)
- Stakeholder management and sustainability oriented communication
- An intro into sustainability issues of supply chain management

Students will get small excercises related to course issues.

Lecture notes
Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on Ilias

Literature
Will be made available.

Prerequisites / notice
This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment, CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

Environmental Engineering Master

Majors

Major Urban Water Management

Ecological System Design

Number Title Type ECTS Hours Lecturers
102-0307-01L Advanced Environmental, Social and Economic Assessments O 5 credits 4G A. E. Braunschweig, S. Pfister, R. Frischknecht

Process Engineering in Urban Water Management

No courses in autumn semester (HS), only in spring semester (FS).

System Analysis in Urban Water Management

Number Title Type ECTS Hours Lecturers
102-0227-00L Systems Analysis and Mathematical Modeling in Urban Water Management O 6 credits 4G E. Morgenroth, M. Maurer
## Process Engineering Ia

### Abstract

### Objective
The goal of this course is to provide the students with an understanding and the tools to develop their own mathematical models, to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

### Content
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

### Literature
There will be a required textbook that students need to purchase:

### Prerequisites / notice
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel with the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Conceptual Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
<th>Problem-solving</th>
<th>Project Management</th>
<th>Sensitivity to Diversity</th>
<th>Negotiation</th>
<th>Adaptability and Flexibility</th>
<th>Creative Thinking</th>
<th>Critical Thinking</th>
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<th>Self-awareness and Self-reflection</th>
<th>Self-direction and Self-management</th>
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### Lecture notes
Copies of overheads will be made available.

### 102-0217-00L

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>ECTS</th>
<th>Credit Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0217-00L</td>
<td>Process Engineering Ia</td>
<td>3</td>
<td>credits</td>
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</table>

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Conceptual Competencies</th>
<th>Analytical Competencies</th>
<th>Decision-making</th>
<th>Media and Digital Technologies</th>
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### Prerequisites / notice
For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be downloaded at http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information.

### Literature

### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
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</table>
## Urban Drainage Planning and Modelling

**Number:** 102-0250-00L  
**Title:** Urban Drainage Planning and Modelling  
**ECTS:** 6 credits  
**Hours:** 4G  
**Lecturers:** M. Maurer, D. Gregorio, U. Karaus, J. P. Leitão Correia, J. Rieckermann  

### Abstract
In this course, the students learn modern urban drainage engineering approaches, critical thinking, decision making in a complex environment as well as dealing with insufficient data and ill-defined problems.

### Objective
By the end of the course, you should be able to do the following:
- Apply different methods and methodologies to assess the impact of urban drainage on water pollution and flooding potential.
- Distinguish between hydrological and hydrodynamic models and their correct application.
- Identify the difference between emission and immersion oriented approaches for identifying drainage measures.
- Identify relevant measures, quantify their effects and assess their relative ranking/priority.
- Consider uncertainties and handle correctly incomplete data and information.
- Make decisions and recommendations in a complex application case.
- Teamwork. State principles of effective team performance and the functions of different team roles; work effectively in problem-solving teams.
- Communication. Communicate and document your findings in concise group presentations and a written report.

### Content
In urban drainage, the complexity of the decision-making, the available methodologies and the data availability have increased strongly. In current environmental engineering practice, the focus shifted from tables and nomograms to sophisticated simulation tools.

The topics cover:
- Integrated urban water management
- Hydrological and hydrodynamic modelling
- Water quality based assessment
- Freshwater ecology
- Hydraulic capacity assessment
- Sewer network operation
- Decision analysis

### Prerequisites / notice
Prerequisites: 102-0214-00 Siedlungswasserwirtschaft and 102-0215-00 Siedlungswasserwirtschaft II or comparable educational background.

### Taught competencies

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<tbody>
<tr>
<td>A</td>
<td>Subject-specific Competencies</td>
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<td>B</td>
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### Major Environmental Technologies

#### Air Quality Control

**Number:** 102-0377-00L  
**Title:** Air Pollution Modeling and Chemistry  
**ECTS:** 3 credits  
**Hours:** 2G  
**Lecturers:** S. Henne, S. Reimann Bhend, X. Zhang  

### Abstract
Air pollutants cause negative effects on humans, wildlife and buildings. To control and reduce the impact of air pollutants, their transfer from sources to receptors needs to be known. This transfer includes transport within the atmospheric boundary layer, chemical transformation reactions and phase-transfer processes from gases to particles.

### Objective
The students understand the fundamental principles of atmospheric transport, dispersion and chemistry of pollutants on the local to regional scale and their transfer gas to particle phases (secondary aerosols). This includes the knowledge of important atmospheric reactions, sources and sinks. The obtained understanding enables the students to apply computational tools to predict the transport and transformation of chemicals at the local to regional scale.

### Content
- Structure of the Atmosphere
- Thermodynamics of the atmosphere
- Atmospheric stability
- Atmospheric boundary layer and turbulence
- Dispersion in the atmospheric boundary layer
- Numerical models of atmospheric dispersion
- Gas phase reaction kinetics
- Tropospheric chemistry and ozone formation
- Chemistry box models
- Volatile organic pollutants (VOCs) and semi-volatile organic pollutants (SVOCs)
- Aerosol modelling
- Air pollution source apportionment
- Inverse modelling of emissions
Lecture notes
Continued updates of:
- Slides and handouts
- Home assignments and sample solutions
- R package and code for some of the home assignments
- MATLAB codes
- Key journal articles as discussed during lecture

Literature
Atmospheric chemistry

Environmental organic chemistry and mass transfer
Mackay D., Multimedia environmental models : the fugacity approach; Boca Raton, Fla. : Lewis Publishers; 2001; 2nd ed

Atmospheric dynamics and boundary layer

Atmospheric modelling

Introduction to R

Prerequisites / notice
strongly recommended: 102-0635-01L Luftreinhaltung (Air Pollution Control) or similar

>>>> Process Engineering in Urban Water Management
No courses in autumn semester (HS), only in spring semester (FS).

>>>> System Analysis in Urban Water Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tr>
<td>102-0227-00L</td>
<td>Systems Analysis and Mathematical Modeling in Urban Water Management</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>E. Morgenroth, M. Maurer</td>
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</table>

Number of participants limited to 50.

Abstract

Objective
The goal of this course is to provide the students with an understanding and the tools to develop their own mathematical models, to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

Content
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

Lecture notes
Copies of overheads will be made available.

Literature
There will be a required textbook that students need to purchase:

Prerequisites / notice
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel with the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies assessed
Problem-solving assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking not assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management not assessed

102-0217-00L Process Engineering Ia
O 3 credits 2G E. Morgenroth
Practices of landfilling and remediation of contaminated sites and disposal of radioactive waste are based on the same concepts that aim to protect the environment. The assessment of contaminants that may leach into the environment as a function of time and how to reduce the rate of their release is key to the design of chemical, technical and geological barriers.

At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

Only for Environmental Engineering MSc.

Upon successful completion of this course students are able to:
- assess the risk posed to the environment of landfills, contaminated sites and radioactive waste repositories in terms of fate and transport of contaminants
- describe technologies available to minimize environmental contamination
- describe the principles in handling of contaminated sites and to propose and evaluate suitable remediation techniques
- explain the concepts that underlie radioactive waste disposal practices

For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be downloaded at http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Remark: 102-0337-00 Landfilling, Contaminated Sites and Radioactive Waste Repositories only for those students also taking module "System Analysis in Urban Water Management" as replacement of 102-0217-00 Process Engineering Ia in module "Waste Management".

### Waste Management

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<tr>
<th>Number</th>
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<tr>
<td>102-0357-00L</td>
<td>Waste Recycling Technologies</td>
<td>O</td>
<td>3 credits</td>
<td>2G</td>
<td>R. Bunge</td>
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</tbody>
</table>

#### Abstract
Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.

#### Objective
At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

#### Content
Waste Recycling: Scope and objectives
Waste recycling technologies in Switzerland

- Fundamentals
  - Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials
  - Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles
  - Flow sheet basics: Balancing mass flows
  - Standard processes: batch vs. continuous
  - Assessment of separation success: Separation function; grade vs. recovery

- Separation Processes
  - Separation according to size and shape (Classification): Screening, Flow separation
  - Separation according to material properties (Concentration): Manual Sorting, Gravity concentration; Magnetic separation, Eddy current separation, Electrostatic separation, Sensor technology, Froth flotation

#### Lecture notes
The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

#### Literature
A list of recommended books will be provided.

- Anaerobic processes, industrial applications, sludge stabilization
  - microbial transformation processes
  - stoichiometry

- Waste Recycling: Scope and objectives
  - waste recycling technologies in Switzerland
  - fundamentals
    - properties of particles: liberation conditions, particle size and shape, porosity of bulk materials
    - fluid dynamics of particles: stationary particle beds, fluidized beds, free settling particles
    - flow sheet basics: balancing mass flows
    - standard processes: batch vs. continuous
    - assessment of separation success: separation function; grade vs. recovery

- separation processes
  - separation according to size and shape (classification): screening, flow separation
  - separation according to material properties (concentration): manual sorting, gravity concentration; magnetic separation, eddy current separation, electrostatic separation, sensor technology, froth flotation
This lecture course comprises of lectures with exercises and guided case studies.
- A short overview of the principles of environmental protection in waste management and how this is applied in legislation.
- A overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity; mobility of heavy metals and organic compounds
- Technical barrier design and function. Clay as a barrier.
- Contaminated site remediation: Site evaluation, remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

Lecture notes
Short script plus copies of overheads

Literature
Content
- Process Engineering Ia
  - Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

Objective
- Students should be able to evaluate and design biological processes. Develop simple mathematical models to simulate treatment processes.

Content
- Stoichiometry
- Microbial transformation processes
- Introduction to design and modeling of activated sludge processes
- Anaerobic processes, industrial applications, sludge stabilization

Literature
- There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

Prerequisites / notice
- For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be downloaded at http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Major Resource Management

Ecological System Design

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
102-0307-01L | Advanced Environmental, Social and Economic Assessments | O | 5 credits | 4G | A. E. Braunschweig, S. Pfister, R. Frischknecht

Abstract
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications.

Objective
This course has the aim of deepening students' knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management
Part I (Advanced Environmental Assessments)
- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

Part II (Implementation of Environmental and other Sustainability Goals):
- Sustainability problems of the current economic system and its measuring units;
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SAS8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication
- Sustainability Opportunities and Innovation
- The concept of ’Continuous Improvement’
- Life Cycle Costing, Life Cycle Management
- environmental performance measurement of an organisation, including ‘organisational LCA’ (Ecobalance), based on practical examples of companies and new concepts
- single score env. assessment methods (Swiss ecopoints)
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Lecture notes Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on Ilias

Literature Will be made available.

Prerequisites / notice This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5,2)).

102-0317-03L Advanced Environmental Assessment (Computer Lab I) O 1 credit 1U S. Pfister

Abstract Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice

Objective Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

Module is offered in Spring Semester.

Waste Management

Remark: 102-0337-00 Landfilling, Contaminated Sites and Radioactive Waste Repositories only for those students also taking module "System Analysis in Urban Water Management" as replacement of 102-0217-00 Process Engineering Ia in module "Waste Management".

Number Title Type ECTS Hours Lecturers
102-0357-00L Waste Recycling Technologies O 3 credits 2G R. Bunge

Abstract Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.

Objective All the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.

Content Introduction Waste Recycling: Scope and objectives
Waste recycling technologies in Switzerland

Fundamentals
- Properties of particles: Liberation conditions, Particle size and shape, Porosity of bulk materials
- Fluid dynamics of particles: Stationary particle beds, Fluidized beds, Free settling particles
- Flow sheet basics: Balancing mass flows
- Standard processes: batch vs. continuous
- Assessment of separation success: Separation function; grade vs. recovery

Separation Processes
- Separation according to size and shape (Classification): Screening, Flow separation
- Separation according to material properties (Concentration): Magnetic separation, Eddy current separation, Electrostatic separation, Sensor technology, Froth flotation

Lecture notes The script consists of the slides shown during the lectures. Background material will be provided on the script-server.

Literature A list of recommended books will be provided.

Prerequisites / notice The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

102-0337-00L Landfilling, Contaminated Sites and Radioactive Waste Repositories for Environmental Engineering MSc.

Abstract Practices of landfilling and remediation of contaminated sites and disposal of radioactive waste are based on the same concepts that aim to protect the environment. The assessment of contaminants that may leach into the environment as a function of time and how to reduce the rate of their release is key to the design of chemical, technical and geological barriers.
Upon successful completion of this course students are able to:
- assess the risk posed to the environment of landfills, contaminated sites and radioactive waste repositories in terms of fate and transport of contaminants
- describe technologies available to minimize environmental contamination
- describe the problem of contaminated sites and to propose and evaluate suitable remediation techniques
- explain the concepts that underlie radioactive waste disposal practices

This lecture course comprises of lectures with exercises and guided case studies.
- A short overview of the principles of environmental protection in waste management and how this is applied in legislation.
- A review of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity, mobility of heavy metals and organic compounds
- Technical barrier design and function. Clay as a barrier.
- Contaminated site remediation: Site evaluation, remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

This lecture course comprises of lectures with exercises and guided case studies.
- A short overview of the principles of environmental protection in waste management and how this is applied in legislation.
- A review of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity, mobility of heavy metals and organic compounds
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- A review of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity, mobility of heavy metals and organic compounds
- Technical barrier design and function. Clay as a barrier.
- Contaminated site remediation: Site evaluation, remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.
In this course, the following topics are discussed: The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated. All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used. The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems - Use of GIS in landscape planning) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

Lecture notes: No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

Prerequisites / notice: The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on Numerical Hydraulics and Adaptability and Flexibility. There is no script.

ECTS: 2G

There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

102-0287-00L  River Basin Erosion  W 3 credits  2G  P. Molnar

Abstract
The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from Hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Objective
The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Content
The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Lecture notes
There is no script.

Literature
The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice
Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

Water Resources Management

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<th>ECTS</th>
<th>Hours</th>
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<tr>
<td>102-0468-10L</td>
<td>Watershed Modelling</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>P. Molnar</td>
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Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical exercises (exercises).

Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling. Here students learn about using watershed models in a case study. Finally, we will learn about how to describe the topology of river networks as conduits of sediment through the fluvial system.

Lecture notes
There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature
The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice
Prerequisites: Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences), Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Major River and Hydraulic Engineering

Flow and Transport

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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>101-0267-01L</td>
<td>Numerical Hydraulics</td>
<td>O</td>
<td>3</td>
<td>2G</td>
<td>M. Holzner</td>
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</tbody>
</table>
In the course Numerical Hydraulics the basics of numerical modelling of flows are presented. The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

At the end of the course, the students will be able to:

- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

At the end of the course, the students will be able to:

- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

Information: Because Hydraulic Structures II is strongly based on Hydraulic Engineering (101-0206-00L) it is strongly recommended to have taken this course (101-0206-00L) or a similar one previously.
Short practical exercises (voluntary) will be offered throughout the semester to improve the application of the learned subjects.

Water Resources Management

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0468-10L</td>
<td>Watershed Modelling</td>
<td>O</td>
<td>6</td>
<td>4G</td>
<td>P. Molnar</td>
</tr>
</tbody>
</table>

Abstract
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

Objective
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block builds on the lectures with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Content
The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

Project Work (for all Majors)

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0999-00L</td>
<td>Project Work</td>
<td>O</td>
<td>12</td>
<td>26A</td>
<td>Supervisors</td>
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</table>

Elective Modules

For all majors.

EM: Air Quality Control

Elective Module for Majors "Resource Management", "River and Hydraulic Engineering" "Urban Water Management" and "Water Resources Management":

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0377-00L</td>
<td>Air Pollution Modeling and Chemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>S. Henne, S. Reimann Bhend, X. Zhang</td>
</tr>
</tbody>
</table>
Abstract
Air pollutants cause negative effects on humans, wildlife and buildings. To control and reduce the impact of air pollutants, their transfer from sources to receptors needs to be known. This transfer includes transport within the atmospheric boundary layer, chemical transformation reactions and phase-transfer processes from gases to particles.

Objective
The students understand the fundamental principles of atmospheric transport, dispersion and chemistry of pollutants on the local to regional scale and their transfer gas to particle phases (secondary aerosols). This includes the knowledge of important atmospheric reactions, sources and sinks. The obtained understanding enables the students to apply computational tools to predict the transport and transformation of chemicals at the local to regional scale.

Content
- Structure of the Atmosphere
- Thermodynamics of the atmosphere
- Atmospheric stability
- Atmospheric boundary layer and turbulence
- Dispersion in the atmospheric boundary layer
- Numerical models of atmospheric dispersion
- Gas phase reaction kinetics
- Tropospheric chemistry and ozone formation
- Chemistry box models
- Volatile organic pollutants (VOCs) and semi-volatile organic pollutants (SVOCs)
- Aerosol modelling
- Air pollution source apportionment
- Inverse modelling of emissions

Lecture notes
Continued updates of:
- Slides and handouts
- Home assignments and sample solutions
- R package and code for some of the home assignments
- MATLAB codes
- Key journal articles as discussed during lecture

Literature
Atmospheric chemistry

Environmental organic chemistry and mass transfer
Mackay D., Multimedia environmental models : the fugacity approach; Boca Raton, Fla.: Lewis Publishers; 2001; 2nd ed

Atmospheric dynamics and boundary layer

Atmospheric modelling

Introduction to R

Prerequisites / notice
strongly recommended: 102-0635-01L Luftreinhaltung (Air Pollution Control) or similar

EM: Ecological System Design
Selective Module for Majors "Environmental Technologies", "River and Hydraulic Engineering" and "Water Resources Management".

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0307-01L</td>
<td>Advanced Environmental, Social and Economic Assessments</td>
<td>W</td>
<td>5</td>
<td>4G</td>
<td>A. E. Braunschweig, S. Pfister, R. Frischknecht</td>
</tr>
</tbody>
</table>

Abstract
This course deepens students' knowledge of environmental, economic, and social assessment methodologies and their various applications.

Objective
This course has the aim of deepening students' knowledge of the environmental, economic and social assessment methodologies and their various applications.

In particular, students completing the course should have the
- ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- knowledge about the current state of the scientific discussion and new research developments
- ability to properly plan, conduct and interpret environmental assessment studies

In the course element "Implementation of Environmental and other Sustainability Goals", students will learn to
- describe key sustainability problems of the current economic system and measuring units.
- describe the management system of an organisation and how to develop a sustainability orientation
- discuss approaches to measure environmental performance of an organisation, including 'organisational LCA' (Ecobalance)
- explain the pros and cons of single score environmental assessment methods
- demonstrate life cycle costing
- interpret stakeholder relations of an organisation
- (if time allows) describe sustainable supply chain management and stakeholder management

Content

Part I (Advanced Environmental Assessments)
- Inventory database developments, transparency, data quality, data completeness, and data exchange formats, uncertainties
- Software tools (MFA, LCA)
- Allocation (multiopt output processes and recycling)
- Hybrid LCA methods
- Consequential and marginal analysis
- Impact assessment of waterborne chemical emissions, sum parameters, mixture toxicity
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Subjectivity in environmental assessments
- Multicriteria Decision Analysis
- Case Studies

Part II (Implementation of Environmental and other Sustainability Goals):
- Sustainability problems of the current economic system and its measuring units
- The structure of a management system, and elements to integrate environmental management (ISO 14001) and social management (SA8000 as well as ISO 26000), especially into strategy development, planning, controlling and communication
- Sustainability Opportunities and Innovation
- The concept of 'Continuous Improvement'
- Life Cycle Costing, Life Cycle Management
- environmental performance measurement of an organisation, including 'organisational LCA' (Ecobalance), based on practical examples of companies and new concepts
- single score env. assessment methods (Swiss ecopoints)
- stakeholder management and sustainability oriented communication
- an intro into sustainability issues of supply chain management

Lecture notes

Part I: Slides and background reading material will be available on lecture homepage
Part II: Documents will be available on ilias

Literature

Will be made available.

Prerequisites / notice

This course should only be elected by students of environmental engineering with a with a Module in Ecological Systems Design. All other students should take the individual courses in Advanced Environmental Assessment and/or Implementation of Environmental and other Sustainability goals (with or without exercise and lab).

Basic knowledge of environmental assessment tools is a prerequisite for this class. Students who have not yet had classwork in this topic are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. (2016). Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2));

102-0317-03L Advanced Environmental Assessment (Computer Lab I) W 1 credit 1U S. Pfister

Abstract

Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice

Objective

Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

Number Title Type ECTS Hours Lecturers
101-0267-01L Numerical Hydraulics W 3 credits 2G M. Holzner

Abstract

The goal of the course is to develop the understanding of the students for numerical simulation of flows to an extent that they can later use commercial software in a responsible and critical way.

Objective

The basic equations are derived from first principles. Possible simplifications relevant for practical problems are shown and their applicability is discussed. Using the example of non-steady state pipe flow numerical methods such as the method of characteristics and finite difference methods are introduced. The finite volume method as well as the method of characteristics are used for the solution of the shallow water equations. Special aspects such as wave propagation and turbulence modelling are also treated.

All methods discussed are applied practically in exercises. This is done using programs in MATLAB which partially are programmed by the students themselves. Further, some generally available softwares such as BASEMENT for non-steady shallow water flows are used.

Literature

Given in lecture

102-0259-00L Ecosyzydraulics and Habitat Modelling W 3 credits 2G R. Stocker, K.-D. Jorde, L. G. Martins da Silva, A. Siviglia

Abstract

At a time in which humans have significantly affected the natural environment and yet society increasingly values the many services of natural ecosystems, accounting for ecological processes in engineering design is a major contemporary challenge for environmental and civil engineers.

Objective

This is the fundamental topic in ecohydraulics, the discipline that focuses on the consequences of fluid flow and related physical processes on the organisms that inhabit aquatic environments. While still a young science, ecohydraulics already endows the engineer with an overall understanding and quantitative tools to predict how physical processes shape habitat quality and quantity, enabling the analysis of different management options for natural and man-made water bodies and their ecosystem consequences.

Content

This class will take a broad view of ecohydraulics and introduce students to key concepts in aquatic habitat modeling. Recognizing that an ecosystem is composed of diverse organisms with different seasonal habitat requirements across a range of scales, the class will focus on multiple representative groups of organisms, including fish, macroinvertebrates, plankton, and vegetation. The lectures will build on the students’ knowledge of hydraulics, to give them both an appreciation for the dependence of organisms on their physical environment and a set of quantitative modeling approaches that they can take with them into engineering practice, in fields ranging from hydropower development and upgrade, to reservoir operation, river restoration, flood protection, water management and beyond. At the broadest scale, this class will contribute to the students’ appreciation of the tight link between the natural and the built or impacted environment, and of the imperatives of considering both in the design process.

EM: Groundwater

Elective Module for Majors "Environmental Technologies", "River and Hydraulic Engineering" and "Urban Water Management".

Module is offered in FS.

EM: Hydraulic Engineering

Elective Module for Majors "Environmental Technologies", "Resource Management", " Urban Water Management" and "Water Resources"
101-0247-01L

**Hydraulic structures II**

*Information: Enrolment of Hydraulic Engineering II is not recommended without having attended Hydraulic Engineering (101-0206-00L) previously since Hydraulic Engineering II is strongly based on Hydraulic Engineering (101-0206-00L).*

**Abstract**

Hydraulic structures and their functions within hydraulic systems are treated in this lecture. The basic concepts of their layout and design with regard to economy and safety are provided.

**Objective**

Knowledge of hydraulic structures and their function within hydraulic systems. Skills for the layout and design of hydraulic structures with regard to economy and safety.

**Content**

Weirs: Weir stability, gates, inflatable dams, appurtenant structures, fish up- and downstream passages.

Conduits: Design of headraces, pressure shafts, and penstocks, constructive details and construction.

Power plants: Power house and turbine types, design, structure, construction.

Dams: Types, appurtenant structures (temporary diversions, spillways, bottom and low-level outlets), dam type selection criteria, layout and design of gravity dams, buttress dams, arch dams, rockfill dams with central core or concrete face, measures in the foundation, mass concrete, RCC dams, reservoir sitiation and sediment management, dam surveillance.

Artificial reservoirs: Purpose, layout, sealing, appurtenant structures, environmental aspects.

**Lecture notes**

Manuscript and further documentation

**Prerequisites / notice**

Information: Because Hydraulic Structures II is strongly based on Hydraulic Engineering (101-0206-00L) it is strongly recommended to have taken this course (101-0206-00L) or a similar one previously.

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**EM: Landscape**

*Elective Module for Majors "Environmental Technologies", "Resource Management", "River and Hydraulic Engineering" and "Urban Water Management".*

101-0347-00L

**Landscape Planning and Environmental Systems**

*Information: Because Hydraulic Engineering II is strongly based on Hydraulic Engineering (101-0206-00L) it is strongly recommended to have taken this course (101-0206-00L) or a similar one previously.*

**Abstract**

In the course, students learn about methods for the identification and measurement of landscape characteristics, as well as measures and policies for landscape planning. Landscape planning is put into the context of environmental systems (soil, water, air, climate, flora and fauna) and discussed with regard to socio-political questions of the future.

**Objective**

The aims of this course are:

1. To illustrate the concept of landscape planning, the economic relevance of landscape and nature in the context of the environmental systems (soil, water, air, climate, flora and fauna).
2. To show landscape planning as an integral information system for the coordination of different instruments by illustrating the aims, methods, instruments and their functions in landscape planning.
3. To show the importance of ecosystem services.
4. To learn basics about nature and landscape: Analysis and assessment of the complex interactions between landscape elements, effects of current and future land use (ecosystem goods and services, landscape functions).
5. To identify and measure the characteristics of landscape.
6. To learn how to use spatial data in landscape planning.

**Content**

In this course, the following topics are discussed:

- Definition of the concept of landscape
- Relevance of landscape planning
- Landscape metrics
- Landscape change
- Methods, instruments and aims of landscape planning (policy)
- Socio-political questions of the future
- Environmental systems, ecological connectivity
- Ecosystem services
- Urban landscape services
- Practice of landscape planning
- Use of GIS in landscape planning

**Lecture notes**

No script. The documentation, consisting of presentation slides are partly handed out and are provided for download on Moodle.

**Prerequisites / notice**

The contents of the course will be illustrated in the associated course 103-0347-01 U (Landscape Planning and Environmental Systems (GIS Exercises)) or in Project LAND within the Experimental and Computer Lab (for Environmental Engineers). A combination of courses is recommended.

**Taught competencies**

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Taught competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
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<td>assessed</td>
</tr>
<tr>
<td>Techniques and Technologies</td>
<td>assessed</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
<th>Taught competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
<td>assessed</td>
<td>assessed</td>
</tr>
<tr>
<td>Decision-making</td>
<td>assessed</td>
<td>assessed</td>
</tr>
<tr>
<td>Media and Digital Technologies</td>
<td>assessed</td>
<td>assessed</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Domain C - Social Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
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</tr>
<tr>
<td>Cooperation and Teamwork</td>
<td>not assessed</td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
</tr>
<tr>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
</tr>
<tr>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
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<tr>
<td>Negotiation</td>
<td>not assessed</td>
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</table>

<table>
<thead>
<tr>
<th>Domain D - Personal Competencies</th>
<th>Taught competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptability and Flexibility</td>
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<tr>
<td>Creative Thinking</td>
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<tr>
<td>Critical Thinking</td>
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<td>Integrity and Work Ethics</td>
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<tr>
<td>Self-awareness and Self-reflection</td>
<td>not assessed</td>
</tr>
<tr>
<td>Self-direction and Self-management</td>
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</tr>
</tbody>
</table>

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The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Objective

The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial system change, using the right language and terminology to describe landforms. We will cover the main geomorphic concepts of landscape change, e.g., thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.

Content

The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-rill-gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Lecture notes

There is no script.

Literature

The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures were developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice

Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

EM: Process Engineering in Urban Water Management

Elective Module for Majors “Resource Management”, “River and Hydraulic Engineering” and “Water Resources Management”.

No courses in autumn semester (HS), only in spring semester (FS).

EM: Remote Sensing and Earth Observation


Remark: Students also taking module “Remote Sensing and Earth Observation” as replacement of 102-0617-01L Methodologies for Image Processing of Remote Sensing Data in module “Landscape” have to chose one out following list:
1. 701-0104-00L Statistical Modelling of Spatial Data (FS) oder
2. 701-1674-00L Spatial Analysis, Modelling and Optimisation (FS) oder
3. 701-1644-00L Mountain Forest Hydrology (HS).

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>102-0617-00L</td>
<td>Basics and Principles of Radar Remote Sensing for Environmental Applications</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>I. Hajnsek</td>
</tr>
</tbody>
</table>

Abstract

The course will provide the basics and principles of Radar Remote Sensing (specifically Synthetic Aperture Radar (SAR)) and its imaging techniques for the use of environmental parameter estimation.

Objective

At the end of the course the student has the understanding of:
1. SAR basics and principles,
2. SAR polarimetry,
3. SAR interferometry and
e. environmental parameter estimation from multi-parametric SAR data

Content

The course is giving an introduction into SAR techniques, the interpretation of SAR imaging responses and the use of SAR for different environmental applications. The outline of the course is the following:
1. Introduction into SAR basics and principles
2. Introduction into electromagnetic wave theory
3. Introduction into scattering theory and decomposition techniques
4. Introduction into SAR interferometry
5. Introduction into polarimetric SAR interferometry
6. Introduction into bio/geophysical parameter estimation (classification/segmentation, soil moisture estimation, earth quake and volcano monitoring, forest height inversion, wood biomass estimation etc.)

Lecture notes

Handouts for each topic will be provided

Literature

First readings for the course:
Complete literature listing will be provided during the course.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0627-00L</td>
<td>Applied Radar Remote Sensing</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>O. Frey</td>
</tr>
</tbody>
</table>

Abstract

This course provides an introduction to processing and interpreting radar and synthetic aperture radar (SAR) remote sensing data. The primary topics of the course are interferometric techniques and related applications such as topography mapping and mapping of surface displacements, with a strong emphasis on solving practical problems using MATLAB.

Objective

Understand the concepts and techniques required to process and to adequately interpret interferometric radar/SAR data for topographic mapping and surface displacement applications.

At the end of the course the student is able to read, display, process, and interpret interferometric radar/SAR using MATLAB.
Content
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective
At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

Content
The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

The rationale behind the structure of the course follows the idea that radar imaging and radar/SAR interferometry are closely related and that a basic understanding of the radar imaging concept is helpful to understand and interpret interferometric radar data for various applications.

The course starts with the real-aperture radar case and a first introduction to the concept of radar interferometry with applications to topographic mapping and mapping of surface displacements.

Based on that, the 2-D imaging concept used in synthetic aperture radar imaging is treated.

Then, we expand further on radar and SAR interferometric (InSAR) concepts and processing steps for single interferograms and stacks of interferograms also using persistent scatterer interferometry (PSI) to measure deformation based on time series of interferometric SAR data.

Finally, the 3-D radar imaging case (SAR tomography) is put into context with PSI/InSAR time series as an extension of the more classical interferometric approaches thereby closing the circle around the strongly related concepts of SAR imaging and interferometry.

Lecture notes
Lecture notes/handouts for each topic will be provided online.

Literature
Additional reading material:
ISBN: 978-0-306-47633-4
https://doi.org/10.1007/0-306-47633-9

Prerequisites / notice
It is highly recommended that the student has previously taken the following courses:
102-0617-00L: Basics and Principles of Radar Remote Sensing
and
102-0617-01L: Methodologies for Image Processing of Remote Sensing Data


Remark: partly in German.

Note: Students taking both of the modules LAND and RIVER must take the course 101-1250-00 Wildbach- und Hangverbau as replacement for for Fluvial Systems that is listed in both modules.

<table>
<thead>
<tr>
<th>Number</th>
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<th>ECTS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>101-0258-00L</td>
<td>River Engineering</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>V. Weitbrecht, I. Schalko, K. Sperger</td>
</tr>
</tbody>
</table>

Abstract
The lecture addresses the fundamentals of river engineering to quantitatively describe the flow of water, transport of sediment and wood, and morphological changes such as erosion and deposition processes associated with river structures. In addition, design guidelines for river engineering structures are introduced.

Objective
At the end of the course, the students will be able to:
- recall and describe the fundamentals of transport processes in rivers,
- apply different calculation approaches and methods to tackle river engineering problems and tasks such as the discharge capacity of a river, scour estimation, or sediment budget of a river,
- design and dimension river engineering works needed to influence the processes in watercourses, and
- determine the interaction between flow (discharge), sediment transport, wood transport and the resulting channel evolution.

Content
The first part of the lecture introduces the fundamentals of river engineering, such as methods to determine and calculate the river discharge, or sampling methods to characterize the bed material. In addition, the transport processes of sediment (bedload and suspended load) and wood in rivers will be examined, including the principles of incipient motion, and initiation of erosion or deposition processes.

In the second part of the lecture, the methods will be explained to quantify the bed load budget and the morphological changes (erosion, deposition) in river systems. Specifically, natural channel formation processes, different bed forms and plan forms of rivers (straight, meandering, braided) are examined.

The last part of the lecture focuses on the design of river engineering structures, including examples from an ongoing flood and river revitalization project at the Alpine Rhine in Austria and Switzerland.

The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial system change, using the right language and terminology to describe landforms. We will cover the main geomorphic concepts of landscape change, e.g. thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simple sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.
The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-riparian gully erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual landslides involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Lecture notes
There is no script.

Literature
The course materials consist of a series of 13 lecture presentations and notes to each lecture. The lectures are developed from textbooks, professional papers, and ongoing research activities of the instructor. All material is on the course webpage.

Prerequisites / notice
Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

EM: Soil

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0535-00L</td>
<td>Environmental Soil Physics/Vadose Zone Hydrology</td>
<td>W</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Carminati, P. U. Lehmann-Grunder</td>
</tr>
<tr>
<td>701-1343-00L</td>
<td>Soil-Plant Water Relations</td>
<td>W</td>
<td>3 credits</td>
<td>2V</td>
<td>A. Carminati</td>
</tr>
</tbody>
</table>

Content
The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

Abstract
Students are able to:
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

Objective
Week 1: Introduction, soil vadose zone, units and definitions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;

Week 2: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

Week 7: Unsataturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow

Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project

Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow, non-steady heat flow

Week 10: Root water uptake and transpiration

Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

Week 12: Summary of lectures; solution of old exam

Week 13: Written semester-end exam

Week 14: Short presentations of Hydrus class projects; discussion of written exam

Literature
Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel
Prerequisites / notice
Vadose Zone Hydrology/Environmental Soil Physics (recommended but not required)

EM: System Analysis in Urban Water Management
Elective Module for Majors “Resource Management”, “River and Hydraulic Engineering” and “Water Resources Management”.

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<th>Number</th>
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<tbody>
<tr>
<td>102-0227-00L</td>
<td>Systems Analysis and Mathematical Modeling in Urban Water Management</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>E. Morgenroth, M. Maurer</td>
</tr>
</tbody>
</table>

**Abstract**

**Objective**
The goal of this course is to provide the students with an understanding and the tools to develop their own mathematical models, to plan experiments, to evaluate error propagation and to test simple process control strategies in the field of process engineering in urban water management.

**Content**
The course will provide a broad introduction into the fundamentals of modeling water treatment systems. The topics are:
- Introduction into modeling and simulation
- The material balance equations, transport processes, transformation processes (kinetics, stoichiometry, conservation)
- Ideal reactors
- Hydraulic residence time distribution and modeling of real reactors
- Dynamic behavior of reactor systems
- Systems analytical tools: Sensitivity, parameter identification, error propagation, Monte Carlo simulation
- Introduction to process control (PID controller, fuzzy control)

**Lecture notes**
Copies of overheads will be made available.

**Literature**
There will be a required textbook that students need to purchase:

**Prerequisites / notice**
Students should have a general understanding of urban water management as many examples are taken from processes relevant to related systems. This course is offered in parallel with the course Process Engineering Ia. It is beneficial but not necessary to follow both courses simultaneously.

**Taught competencies**
- Domain A - Subject-specific Competencies
  - Concepts and Theories
  - Analytical Competencies
  - Media and Digital Technologies
  - Problem-solving

- Domain B - Method-specific Competencies
  - Decision-making
  - Media and Digital Technologies
  - Problem-solving
  - Project Management

- Domain C - Social Competencies
  - Communication
  - Leadership and Responsibility
  - Self-presentation and Social Influence
  - Sensitivity to Diversity

- Domain D - Personal Competencies
  - Adaptable and Flexible
  - Creative Thinking
  - Critical Thinking

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<tr>
<td>102-0217-00L</td>
<td>Process Engineering Ia</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>E. Morgenroth</td>
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</tbody>
</table>

**Abstract**
Biological processes used in wastewater treatment, organic waste management, biological resource recovery. Focus on fundamental principles of biological processes and process design based on kinetic and stoichiometric principles. Processes include anaerobic digestion for biogas production and aerobic wastewater treatment.

**Objective**
Students should be able to evaluate and design biological processes. Develop simple mathematical models to simulate treatment processes.

**Content**
Stoichiometry
Microbial transformation processes
Introduction to design and modeling of activated sludge processes
Anaerobic processes, industrial applications, sludge stabilization

**Literature**
There will be a textbook that students need to purchase (see http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html for further information).

**Prerequisites / notice**
For detailed information on prerequisites the student should consult the lecture program and important information (syllabus) of Process Engineering Ia that can be downloaded at http://www.sww.ifu.ethz.ch/education/lectures/process-engineering-ia.html
EM: Waste Management

Elective Module for Majors "River and Hydraulic Engineering" "Urban Water Management" and "Water Resources Management".

Remark: 102-0337-00 Landfilling, Contaminated Sites and Radioactive Waste Repositories only for those students also taking module "System Analysis in Urban Water Management" as replacement of 102-0217-00 Process Engineering Ia in module "Waste Management".

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<td>Communication</td>
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<td>Cooperation and Teamwork</td>
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<td>Customer Orientation</td>
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<td>Leadership and Responsibility</td>
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<td>Self-presentation and Social Influence</td>
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<td>Sensitivity to Diversity</td>
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<td>Negotiation</td>
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<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
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<td>Creative Thinking</td>
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<td>Critical Thinking</td>
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<td></td>
<td>Integrity and Work Ethics</td>
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<td>Self-awareness and Self-reflection</td>
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<td></td>
<td>Self-direction and Self-management</td>
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102-0337-00L Landfilling, Contaminated Sites and Radioactive Waste Repositories

Only for Environmental Engineering MSc.

Abstract
Practices of landfilling and remediation of contaminated sites and disposal of radioactive waste are based on the same concepts that aim to protect the environment. The assessment of contaminants that may leach into the environment as a function of time and how to reduce the rate of their release is key to the design of chemical, technical and geological barriers.

Objective
Upon successful completion of this course students are able to:
- assess the risk posed to the environment of landfills, contaminated sites and radioactive waste repositories in terms of fate and transport of contaminants
- describe technologies available to minimize environmental contamination
- describe the principles in handling of contaminated sites and to propose and evaluate suitable remediation techniques
- explain the concepts that underlie radioactive waste disposal practices
This lecture course comprises of lectures with exercises and guided case studies.
- A short overview of the principles of environmental protection in waste management and how this is applied in legislation.
- A overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity; mobility of heavy metals and organic compounds
- Technical barrier design and function. Clay as a barrier.
- Contaminated site remediation: Site evaluation, remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

- A list of recommended books will be provided.

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- A short overview of the principles of environmental protection in waste management and how this is applied in legislation.
- A overview of the chemistry underlying the release and transport of contaminants from the landfilled/contaminated material/radioactive waste repository focusing on processes that control redox state and pH buffer capacity; mobility of heavy metals and organic compounds
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- Contaminated site remediation: Site evaluation, remediation technologies
- Concepts and safety in radioactive waste management
- Role of the geological and engineered barriers and radionuclide transport in geological media.

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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>102-0357-00L</td>
<td>Waste Recycling Technologies</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. Bunge</td>
</tr>
<tr>
<td>Abstract</td>
<td>Waste Recycling Technology (WRT) is a sub-discipline of Mechanical Process Engineering. WRT is employed in production plants processing contaminated soil, construction wastes, scrap metal, recovered paper and the like. While WRT is well established in Central Europe, it is only just now catching on in emerging markets as well.</td>
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<tr>
<td>Objective</td>
<td>At the core of this course is the separation of mixtures of solid bulk materials according to physical properties such as color, electrical conductivity, magnetism and so forth. After having taken this course, the students should have concept not only of the unit operations employed in WRT but also of how these unit operations are integrated into the flow sheets of production plants.</td>
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<tr>
<td>Content</td>
<td>Introduction</td>
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<td></td>
<td>Waste Recycling: Scope and objectives</td>
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<td>Waste recycling technologies in Switzerland</td>
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<tr>
<td>Lecture notes</td>
<td>The script consists of the slides shown during the lectures. Background material will be provided on the script-server.</td>
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<tr>
<td>Literature</td>
<td>A list of recommended books will be provided.</td>
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</table>

**Prerequisites / notice**
- Notice: The topic will be discussed not from the perspective of theory, but rather in the context of practical application. However, solid fundamentals in physics (in particular in mechanics) are strongly recommended.

#### EM: Water Infrastructure Planning and Stormwater Management


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<tr>
<th>Number</th>
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<tbody>
<tr>
<td>102-0250-00L</td>
<td>Urban Drainage Planning and Modelling</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>M. Maurer, D. Gregorio, U. Karaus, J. P. Leitão Correia, J. Rieckermann</td>
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<tr>
<td>Abstract</td>
<td>In this course, the students learn modern urban drainage engineering approaches, critical thinking, decision making in a complex environment as well as dealing with insufficient data and ill-defined problems.</td>
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<tr>
<td>Objective</td>
<td>By the end of the course, you should be able to do the following:</td>
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<td>- Apply different methods and methodologies to assess the impact of urban drainage on water pollution and flooding potential.</td>
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<td>- Distinguish between hydrological and hydrodynamic models and their correct application.</td>
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<td>- Identify the difference between emission and immersion oriented approaches for identifying drainage measures.</td>
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<td>- Identify relevant measures, quantify their effects and assess their relative ranking/priority.</td>
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<td>- Consider uncertainties and handle correctly incomplete data and information</td>
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<td>- Make decisions and recommendations in a complex application case.</td>
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<td>- Teamwork. State principles of effective team performance and the functions of different team roles; work effectively in problem-solving teams.</td>
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<td>- Communication. Communicate and document your findings in concise group presentations and a written report.</td>
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<tr>
<td>Content</td>
<td>In urban drainage, the complexity of the decision-making, the available methodologies and the data availability have increased strongly. In current environmental engineering practice, the focus shifted from tables and nomograms to sophisticated simulation tools. The topics cover:</td>
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<td>- Integrated urban water management</td>
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<td>- Hydrological and hydrodynamic modelling</td>
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<td>- Water quality based assessment</td>
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<td>- Freshwater ecology</td>
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<td>- Hydraulic capacity assessment</td>
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<td>- Sewer network operation</td>
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<td></td>
<td>- Decision analysis</td>
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<tr>
<td>Prerequisites / notice</td>
<td>Prerequisites: 102-0214-00 Siedlungswasserwirtschaft and 102-0215-00 Siedlungswasserwirtschaft II or comparable educational background.</td>
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</table>
The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on a model of four parts: (A) watershed properties, (B) conceptual watershed models, (C) physically-based model components, and (D) personal competencies. The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models, students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

### Content

- **Objective:** The aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on a model of four parts: (A) watershed properties, (B) conceptual watershed models, (C) physically-based model components, and (D) personal competencies.

- **Abstract:** The course is designed to provide students with a comprehensive understanding of watershed modelling, from conceptual to physically-based models, parameter calibration, and model validation. Students will learn about GIS applications in hydrology and how to simulate stochastic climate for model driving.

- **Prerequisites / notice:** Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

### EM: Water Resources Management

_Elective Module for Majors “Environmental Technologies”, and “Urban Water Management”._

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0468-10L</td>
<td>Watershed Modelling</td>
<td>W</td>
<td>6</td>
<td>4G</td>
<td>P. Molnar</td>
</tr>
</tbody>
</table>

- **Course:** Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

- **Abstract:** Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

- **Objective:** The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on a model of four parts: (A) watershed properties, (B) conceptual watershed models, (C) physically-based model components, and (D) personal competencies. The first part (A) of the course is on watershed properties analysed from DEMs, and on global sources of hydrological data for modelling applications. Here students learn about GIS applications (ArcGIS, Q-GIS) in hydrology - flow direction routines, catchment morphometry, extracting river networks, and defining hydrological response units. In the second part (B) of the course on conceptual watershed models, students build their own simple bucket model (Matlab, Python), they learn about performance measures in modelling, how to calibrate the parameters and how to validate models, about methods to simulate stochastic climate to drive models, uncertainty analysis. The third part (C) of the course is focussed on physically-based model components. Here students learn about components for soil water fluxes and evapotranspiration, they practice with a fully-distributed physically-based model Topkapi-ETH, and learn about other similar models. They apply Topkapi-ETH to an alpine catchment and study simulated discharge, snow, soil moisture and evapotranspiration spatial patterns. The final part (D) of the course provides open classroom discussion and simulation of a round-table discussion between modellers and clients about using watershed models in a case study.

- **Lecture notes:** There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

- **Literature:** Literature consist of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

- **Prerequisites / notice:** Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).
**Elctives**

The entire course programs of ETH Zurich and the University of Zurich are open to the students to individual selection.

**Course Catalogue of ETH Zurich**

**Master's Thesis**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0010-01L</td>
<td>Master's Thesis</td>
<td>W</td>
<td>30 credits</td>
<td>64D</td>
<td>Supervisors</td>
</tr>
</tbody>
</table>

**Abstract**

The Master Programme concludes with the Master Thesis, which has to be done in one of the chosen Majors and has to be completed within 28 weeks. The Master Thesis is supervised by a professor and shall attest the students ability to work independently and to produce scientifically structured work.

**Objective**

To work independently and to produce a scientifically structured work.

**Content**

The topics of the Master Thesis are published by the professors. The Topic can be set also in consultation between the student and the professor.

**GESS Science in Perspective**

- see GESS Science in Perspective: Language Courses ETH/UZH
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

**Recommended GESS Science in Perspective (Type B) for D-BAUG.**

**Course Units for Additional Admission Requirements**

The courses below are only available for MSc students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0203-AAL</td>
<td>Hydraulics I</td>
<td>E-</td>
<td>5 credits</td>
<td>11R</td>
<td>R. Stocker</td>
</tr>
</tbody>
</table>

**Abstract**

The course teaches the basics of hydromechanics, relevant for civil and environmental engineers.

**Objective**

Familiarization with the basics of hydromechanics of steady state flows

**Content**

Properties of water, hydrostatics, continuity, Euler equation of motion, Navier Stokes equaion, similarity, Bernoulli principle, momentum equation for finite volumes, ideal fluids-real fluids, boundary layer, pipe flow, open channel flow, flow in porous media, flow measurements, demonstration experiments in the lecture hall and in the laboratory

**Lecture notes**

Script and collection of problems available

**Literature**

Bolirich, Technische Hydromechanik 1, Verlag Bauwesen, Berlin

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>102-0214-AAL</td>
<td>Introduction to Urban Water Management</td>
<td>E-</td>
<td>6 credits</td>
<td>13R</td>
<td>E. Morgenroth, M. Maurer</td>
</tr>
</tbody>
</table>

**Abstract**

Introduction to urban water management (water supply, urban drainage, wastewater treatment, sewage sludge treatment). Introduction to Urban Water Management is a self-study course.

**Objective**

This course provides an introduction and an overview over the topics of urban water management (water supply, urban drainage, wastewater treatment, sewage sludge treatment). It supports the understanding of the interactions of the relevant technical and natural systems. Simple design models are introduced.

**Content**

Overview over the field of urban water management, Introduction into systems analysis, Characterization of water and water quality, Requirement of drinking water, production of wastewater and pollutants Production and supply of drinking water, Urban drainage, treatment of combined sewer overflow, Wastewater treatment, nutrient elimination, sludge handling, Planning of urban water infrastructure.
### Literature

In this self-study course the students must work through and understand selected sections from the following book:


Students must understand and be able to discuss the required reading in a 30 min oral exam. The required reading is explained in detail on the website of the professorships of urban water management. Additional information can be asked during the office hours of the professors’ assistants.

The required reading and studying should correspond roughly the time invested in the course Siedlungswasserwirtschaft GZ. Students are welcome to ask the assistants (http://www.sww.ifu.ethz.ch/group/teaching-assistants.html) for help with questions they have regarding the reading.

### Prerequisites / notice

Some students joining the MSc program in Environmental Engineering at ETH Zürich have to take additional courses from our BSc program. The decision of what courses to take is done at the time of admission at ETH.

The course on “Introduction to Urban Water Management” is offered at ETH Zürich only in German. Students who can speak and understand German must take the course (Siedlungswasserwirtschaft GZ) and get a passing grade. For students that do not have sufficient German language skills there is a self-study course and they have to take an oral exam.

This course is required for further in depth courses in urban water management.

### Prerequisite: Hydraulics I and Hydrology

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Period</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0324-AAL</td>
<td>Ecological Systems Analysis</td>
<td>6</td>
<td>13R</td>
<td>S. Pfister</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Abstract

Methodological basics and application of various environmental assessment tools.

Objective

- Students learn about environmental assessment tools, such as material flow analysis, risk assessment, and life cycle assessment. They can identify and apply the appropriate tool in a given situation. Also, they are able to critically assess existing studies.

Content

- Methodological basics of material flow analysis, risk assessment, and life cycle assessment
- Application of these methods to case studies

Lecture notes

No script, but literature available on moodle

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Period</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0325-AAL</td>
<td>Waste Management</td>
<td>4</td>
<td>9R</td>
<td>C. Leitzinger</td>
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<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.</td>
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</tbody>
</table>

Abstract

Introduction into the problems of waste handling with the goal to get the ability of seeing and improving the influence of commodities and products with there packaging to the environment - as they are becoming waste. Knowing the different mechanical and chemical processes, which are applicable in the field of waste management.

Objective

- To reconstruct the historical development of the waste problems
- To know the problems of a modern waste management
- To see and to improve the influence of commodities and products to the environment
- To recognize waste and his components as raw material and resources and to get the know how for a correct handling
- To know the different mechanical and chemical processes, which are applicable in the field of waste management

Content

This lecture gives a comprehensive overview of the different waste-types and waste handling possibilities:

- Waste composition as a mirror of the human evolution
- Waste definition (formation, amount, energy content, waste composition)
- Several recycling possibilities and processes
- Thermal waste treatment (electricity/district heat as products), including off-gas cleaning and incineration residue handling with regards to the final residue storage in a landfill and the problems which have to be solved there
- Special fields like biological waste handling (composting, fermentation), handling of special wastes and municipal sewage sludge treatment
- Economical aspects

Lecture notes

Martin F. Lemann, Christoph Leitzinger, Leo S. Morf: Waste Management Edition 2020, 433 pages
ISBN 978-3-9525297-0-6

Literature

Martin F. Lemann, Christoph Leitzinger, Leo S. Morf: Waste Management Edition 2020, 433 pages
ISBN 978-3-9525297-0-6

Prerequisites / notice

basic of chemical processes has to be known
<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td></td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td></td>
<td>not assessed</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Critical Thinking</td>
<td></td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td></td>
<td>not assessed</td>
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<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td></td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td></td>
<td>not assessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>ECTS</th>
<th>Tutor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0455-AAL</td>
<td>Groundwater I</td>
<td>E-4</td>
<td>9R</td>
<td>J. Jimenez-Martinez, M. Willmann</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td>The course provides a quantitative introduction to groundwater flow and contaminant transport.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td>Understanding of the basic concepts on groundwater flow and contaminant transport processes. Formulation and solving of practical problems.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
<td></td>
<td>Properties of porous and fractured media, Darcy’s law, flow equation, stream functions, interpretation of pumping tests, transport processes, transport equation, analytical solutions for transport, numerical methods: finite differences method, aquifers remediation, case studies.</td>
</tr>
</tbody>
</table>
W. Kinzelbach, R. Rausch, Grundwassermodellierung, Gebrüder Bornträger, Stuttgart, 1995 |

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<th>ECTS</th>
<th>Tutor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0635-AAL</td>
<td>Air Pollution Control</td>
<td>E-6</td>
<td>13R</td>
<td>J. Wang, B. Buchmann</td>
</tr>
<tr>
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<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td>The lecture provides an introduction to the formation of air pollutants by technical processes, the emission of these chemicals into the atmosphere and the impact on air quality. Theoretical description and modeling of these processes, air quality measurement techniques and pollution control techniques are covered.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td>The students gain general knowledge of the factors resulting in air pollution and the techniques used for air pollution control. The students can identify major air pollution sources and understand the methods for measurement, data collection and analysis. The students can evaluate possible control methods and equipment, design a control system and estimate the efficiency and cost.</td>
</tr>
</tbody>
</table>
|             | Content                               |         |      | - the physical and chemical processes leading to emission of pollutants
- air quality analysis
- the meteorological parameters influencing air pollution dispersion
- deterministic and stochastic models, describing the air pollution dispersion
- measurement concepts to observe ambient air pollution
- removal of gaseous pollutants by absorption and adsorption
- control of NOx and SOx
- fundamentals of particulate control
- design and application of wet scrubbers |
|             | Literature                            |         |      | Text book
|             | Prerequisites / notice                 |         |      | College lectures on basic physics, chemistry and mathematics. |

<table>
<thead>
<tr>
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<th>ECTS</th>
<th>Tutor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102-0474-AAL</td>
<td>Introduction to Water Resources Management</td>
<td>E-4</td>
<td>4R</td>
<td>P. Burlando</td>
</tr>
<tr>
<td></td>
<td>Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Abstract</td>
<td></td>
<td></td>
<td>The course offers an introduction to the basics of water resources analysis and management covering the topics of water demand vs availability, water exploitation and reservoir design, aquatic physics, water quality and pollution, water conservation and remediation in rivers, lakes and aquifers, sustainable water use.</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td></td>
<td></td>
<td>Introduction to the basics of sustainable water resources management based on relevant hydrological processes, management approaches and mathematical models.</td>
</tr>
</tbody>
</table>

Example of application of modelling techniques are made available on selected topics. Four computer-based class exercises on selected topics are offered and guided through teaching assistants.

Lecture notes
Handouts of slides and additional reading material are provided on the Moodle course webpage (https://moodle-app2.let.ethz.ch/course/view.php?id=14738)

Literature
Literature information is provided either in the handouts or on the Moodle course webpage (https://moodle-app2.let.ethz.ch/course/view.php?id=14738)

Prerequisites / notice
Knowledge from the course “Hydrology” (3rd semester Environmental Engineering) and about basic statistics and probability theory is a prerequisite (not formal).

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Problem-solving

Domain D - Personal Competencies
Creative Thinking
Critical Thinking

252-0846-AAL Computer Science II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
The students will be able to write simple programs and to modify existing programs.

Content
This course offers an introduction to variables, control structures (branch, loop), algorithms and data structures, as well as an outlook to modularisation and object oriented techniques.

Prerequisites / notice
Prerequisites:
252-0845-00 Computer Science I (D-BAUG)

529-2001-AAL Chemistry I and II
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
General Chemistry I and II: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium, kinetics, acids and bases, electrochemistry

Objective
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

Content
1. Stoichiometry
2. Atoms and Elements (Quantenmechanical Model of the Atom)
3. Chemical Bonding
4. Thermodynamics
5. Chemical Kinetics
6. Chemical Equilibrium (Acids and Bases, Solubility Equilibria)
7. Electrochemistry

Lecture notes
Nivaldo J. Tro
Chemistry - A molecular Approach (Pearson), Chapter 1-18

Literature
Housecroft and Constable, CHEMISTRY
Oxtoby, Gillis, Nachtrieb, MODERN CHEMISTRY

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

529-2002-AAL - Chemistry II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement. Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Chemistry II: Redox reactions, chemistry of the elements, introduction to organic chemistry

Objective
Erweitern der allgemeinen Grundlagen und Erarbeiten einer Basis, um Prozesse in komplexeren Umweltsystemen (Wasser / Luft / Boden) in ihrem zeitlichen und quantitativen Ablauf verstehen und beurteilen zu können.

Content
1. Redox reactions
2. Inorganic Chemistry
   Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.
3. Introduction to organic chemistry
   Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups.
   Stereochemistry.
   Reaction mechanisms: SN1- and SN2-reactions, electrophilic aromatic substitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carboxylic and carboxyl groups.
   Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronoc structure of the elements.

Lecture notes

Literature


752-0100-AAL - Biochemistry

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Abstract

Objective

Content

Lecture notes

Literature


Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo.

Objective
Biochemistry of metabolism: Those completing the course will be able to describe and understand fundamental cellular metabolic processes.

Content
Program
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Carbohydrates, structure of DNA
Lipids and biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis
The citric acid cycle
Oxidative phosphorylation
Fatty acid metabolism

Lecture notes
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Literature
by Laurence A. Moran (Author), Robert A Horton (Author), Gray Scrimgeour (Author), Marc Perry (Author)

Prerequisites / notice
Basic knowledge in biology and chemistry is a precondition.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies
assessed

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management
not assessed

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation
not assessed

Domain D - Personal Competencies
Adaptability and Flexibility
Creative Thinking
Critical Thinking
not assessed

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Teaching of basic knowledge in microbiology.

Objective
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Content
This self-study course is based on the book ‘Brock, Biology of Microorganisms’.

Literature
This self-study course is based on the book ‘Brock, Biology of Microorganisms’.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Teaching of basic knowledge in microbiology.

Objective
This is a self-study course for students with microbiology as an admission requirement. The goal of the course is that students acquire basics in microbiology, including bacterial cell biology, genetics, growth and physiology, metabolism, phylogeny and microbial diversity, and applications of microbiology.

Content
This self-study course is based on the book ‘Brock, Biology of Microorganisms’.

Literature
This self-study course is based on the book ‘Brock, Biology of Microorganisms’.
Content

Der hydrologische Kreislauf: globale Wasserressourcen, Wasserbilanz, räumliche und zeitliche Dimension der hydrologischen Prozesse.

Niederschlag: Niederschlagsmechanismen, Regenmessung, räumliche/zeitliche Verteilung des Regens, Niederschlagsregime, Punktniederschlag/Gebietsniederschlag, Isohyeten, Thiesenpolygon, Extremniederschlag, Dimensionierungsnienderschlag.

Interzeption: Messung und Schätzung.

Evaporation und Evapotranspiration: Prozesse, Messung und Schätzung, potentielle und effektive Evapotranspiration, Energiebilanzmethode, empirische Methode.

Infiltration: Messung, Horton-Gleichung, empirische und konzeptionelle Methoden, F-Index und Prozenteuale Methode, SCS-CN Methode.


Schnee und Eis: Schneeeigenschaften und -messungen Schätzung des Schneeschmelzprozesses durch die Energiebilanzmethode, Abluss aus Schneeschmelze, Temperatur-Index- und Grad-Tag-Verfahren.


Lecture notes

Ein internes Skript ist zur Verfügung (kostenpflichtig, nur Herstellungskosten)

Literature


Prerequisites / notice

Die Kopie der Folien zur Vorlesung können auf den Webseiten der Professor für Hydrologie und Wasserwirtschaft herunterladen werden.

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Physics

E- 7 credits 15R S. Johnson

406-0023-AAL

Abstract

This course gives an overview of important concepts in classical dynamics, thermodynamics, electromagnetism, quantum physics, and special relativity. Emphasis is placed on demonstrating key phenomena using experiments, and in developing skills for quantitative problem solving.

Objective

The goal of this course is to make students able to explain and apply the basic principles and methodology of physics to problems of interest in modern science and engineering. An important component of this is learning how to solve new, complex problems by breaking them down into parts and applying approximations.

Content

Oscillations and waves in matter

Thermodynamics (temperature, heat, equations of state, laws of thermodynamics, entropy, transport)

Electromagnetism (electrostatics, magnetostatics, circuits, Maxwell's equations, electromagnetic waves, induction, electromagnetic properties of materials)

Overview of quantum and atomic physics

Introduction to special relativity

Lecture notes

Lecture notes and exercise sheets will be distributed via Moodle.

Literature

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: not assessed
- Integrity and Work Ethics: not assessed
- Leadership and Responsibility: not assessed
- Negotiation: not assessed
- Self-presentation and Social Influence: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: assessed

Stochastics (Probability and Statistics)

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)
- Ch 1: The Role of Statistics
- Ch 2: Populations, Samples, and Probability Distributions
- Ch 3: Binomial Distributions
- Ch 6: Sampling Distribution of Averages
- Ch 7: Normal Distributions
- Ch 8: Student's t Distribution
- Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
- Ch 1: Basics
- Ch 2: The R Environment
- Ch 3: Probability and distributions
- Ch 4: Descriptive statistics and tables
- Ch 5: One- and two-sample tests
- Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435

  From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

Linear Algebra

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to Linear Algebra and Numerical Analysis for Engineers. This reading course is based on chapters from the book "Introduction to Linear Algebra" by Gilbert Strang (SIAM 2009), and "A first Course in Numerical Methods" by U. Ascher and C. Greif (SIAM, 2011).

Objective
To acquire basic knowledge of Linear Algebra and some aspects of related numerical methods and the ability to apply basic algorithms to simple problems.
Content
1 Introduction, calculations using MATLAB
2 Linear systems I
3 Linear systems II
4 Scalar- & vector product
5 Basics of matrix algebra
6 Linear maps
7 Orthogonal maps
8 Trace & determinant
9 General vectorspaces
10 Metric & scalar products
11 Basis, basis transform & similar matrices
12 Eigenvalues & eigenvectors
13 Spectral theorem & diagonalisation
14 Repetition

Literature

Prerequisites / notice
Knowledge of elementary calculus

<table>
<thead>
<tr>
<th>406-0242-AAL</th>
<th>Analysis II</th>
<th>E-</th>
<th>7 credits</th>
<th>15R</th>
<th>M. Akveld</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Mathematical tools of an engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Mathematics as a tool to solve engineering problems, mathematical formulation of problems in science and engineering. Basic mathematical knowledge of an engineer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Literature   | Textbooks in English:  
- J. Stewart: Multivariable Calculus, Thomson Brooks/Cole  
- V. I. Smirnov: A course of higher mathematics. Vol. II. Advanced calculus  
- M. Akveld, R. Sperb, Analysis II, vdf  
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag |

<table>
<thead>
<tr>
<th>406-0243-AAL</th>
<th>Analysis I and II</th>
<th>E-</th>
<th>14 credits</th>
<th>30R</th>
<th>M. Akveld</th>
</tr>
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<tbody>
<tr>
<td>Abstract</td>
<td>Mathematical tools for the engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Mathematics as a tool to solve engineering problems. Basic mathematical knowledge for engineers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Complex numbers. Calculus for functions of one variable with applications. Simple Mathematical models in engineering.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Literature   | Textbooks in English:  
Textbooks in German:  
- M. Akveld, R. Sperb: Analysis I, vdf  
- M. Akveld, R. Sperb: Analysis II, vdf  
- L. Papula: Mathematik für Ingenieure und Naturwissenschaftler, Vieweg Verlag  
- L. Papula: Mathematik für Ingenieure 2, Vieweg Verlag |

Environmental Engineering Master - Key for Type
O                          Compulsory
W+                         Eligible for credits and recommended
W                          Eligible for credits
Z                          Courses outside the curriculum
Dr                         Suitable for doctorate

Key for Hours
V                          lecture
G                          lecture with exercise
U                          exercise
S                          seminar
K                          colloquium
P                          practical/laboratory course
A                          independent project
D                          diploma thesis
R                          revision course / private study
ECTS                      European Credit Transfer and Accumulation System
Special students and auditors need special permission from the lecturers.
This course looks into scientific theories and also empirical understanding of research methods used in the empirical human sciences.

**Abstract**
This course looks into scientific theories and also empirical studies on human learning and relates them to the school.

**Objective**
Anyone wishing to be a successful teacher must first of all understand the learning process. Against this background, theories and findings on the way humans process information and on human behaviour are prepared in such a manner that they can be used for planning and conducting lessons. Students additionally gain an understanding of what is going on in learning and behavioural research so that teachers are put in a position where they can further educate themselves in the field of research into teaching and learning.

**Content**
Thematische Schwerpunkte:
Lernen als Verhaltensänderung und als Informationsverarbeitung: Das menschliche Gedächtnis unter besonderer Berücksichtigung der Verarbeitung symbolischer Information; Lernen als Wissenskonstruktion und Kompetenzerwerb unter besonderer Berücksichtigung des Wissenstransfer; Lernen durch Instruktion und Erklärungen: Die Rolle von Emotion und Motivation beim Lernen; Interindividuelle Unterschiede in der Lernfähigkeit und ihre Ursachen; Intelligenztheorien, Geschlechtsunterschiede beim Lernen

Lernformen:

**Lecture notes / Literature**
Folien werden zur Verfügung gestellt.


**Prerequisites / notice**
This course is only apt for students who intend to enrol in the program "Lehrdiplom" or "Didaktisches Zertifikat". It is about learning in childhood and adolescence.

---

**Educational Science**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturer</th>
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<tbody>
<tr>
<td>851-0240-00L</td>
<td>Human Learning (EW1)</td>
<td>O</td>
<td>2 credits</td>
<td>2V</td>
<td>E. Stern</td>
</tr>
<tr>
<td>851-0242-06L</td>
<td>Cognitively Activating Instructions in MINT Subjects</td>
<td>W</td>
<td>2 credits</td>
<td>2S</td>
<td>R. Schumacher</td>
</tr>
<tr>
<td>851-0242-07L</td>
<td>Human Intelligence</td>
<td>W</td>
<td>1 credit</td>
<td>1S</td>
<td>E. Stern</td>
</tr>
<tr>
<td>851-0242-08L</td>
<td>Research Methods in Educational Science</td>
<td>W</td>
<td>1 credit</td>
<td>2S</td>
<td>P. Edelsbrunner, T. Braas, C. M. Thurn</td>
</tr>
<tr>
<td>851-0240-22L</td>
<td>Coping with Psychosocial Demands of Teaching (EW4 W DZ)</td>
<td>W</td>
<td>2 credits</td>
<td>3S</td>
<td>U. Markwalder, S. Maurer, S. Peterander-Rüschoff</td>
</tr>
</tbody>
</table>

---

Environmental Education Didactics supplies the basic concepts for the application of the contents of the lecture Human Learning (EW 1) in environmental education.

- To familiarize students with gender issues in the educational and STEM context and with controversies regarding these issues
- To develop a critical view on existing research and perspectives.
- To integrate this knowledge with teacher’s work.

Why do fewer women than men specialize in STEM (science, technology, engineering and mathematics)? Are girls better in language and boys better in math? These and other questions about gender differences relevant to education and STEM learning have been occupying researchers for decades. In this seminar, students learn about major gender issues in the educational context and the different perspectives for understanding them.

The seminar builds on the active participation of students in reading, presenting and critically discussing selected papers in the field. We focus on empirical research and integrate implications for the classroom context. In a final small-group assignment, students integrate and elaborate on the topics learned in the seminar.

Prerequisite: Successful participation in the course 851-0240-00L Human Learning (EW1).

► Subject Didactics and Professional Training

**Environmental Education Didactics I**

- Enrollment only possible with matriculation in Teaching Diploma or Teaching Certificate (excluding Teaching Diploma Sport).
- Prerequisite: students should be taking the course 851-0240-00L Human Learning (EW1) in parallel, or to have successfully completed it.

**Number of participants limited to 30.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0823-00L</td>
<td>Environmental Education Didactics I</td>
<td>O</td>
<td>4</td>
<td>3G</td>
<td>C. Colberg, F. Keller</td>
</tr>
</tbody>
</table>

**Environmental Studies**

Target group: Teaching Certificate: Environment Studies.

- Prerequisite: successful participation in Mentored Assignment (701-0822-00L).

**Teaching Internship Including Examination Lessons**

Repetition of the Teaching Internship is excluded even if Examination Lessons are to be repeated.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0827-00L</td>
<td>Teaching Internship Including Examination Lessons</td>
<td>O</td>
<td>6</td>
<td>13P</td>
<td>C. Colberg, F. Keller</td>
</tr>
</tbody>
</table>

**Important:** You can only enrol in the courses of this category if you have not more than 12 CP left for possible additional requirements.
## Environmental Studies TC - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
</tr>
<tr>
<td>E-</td>
<td>Recommended, not eligible for credits</td>
</tr>
<tr>
<td>Z</td>
<td>Courses outside the curriculum</td>
</tr>
<tr>
<td>Dr</td>
<td>Suitable for doctorate</td>
</tr>
</tbody>
</table>

## Key for Hours

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>V</td>
<td>lecture</td>
</tr>
<tr>
<td>G</td>
<td>lecture with exercise</td>
</tr>
<tr>
<td>U</td>
<td>exercise</td>
</tr>
<tr>
<td>S</td>
<td>seminar</td>
</tr>
<tr>
<td>K</td>
<td>colloquium</td>
</tr>
<tr>
<td>P</td>
<td>practical/laboratory course</td>
</tr>
<tr>
<td>A</td>
<td>independent project</td>
</tr>
<tr>
<td>D</td>
<td>diploma thesis</td>
</tr>
<tr>
<td>R</td>
<td>revision course / private study</td>
</tr>
</tbody>
</table>

**ECTS**
European Credit Transfer and Accumulation System

- Special students and auditors need special permission from the lecturers.
# Environmental Sciences Bachelor

## Basic Courses I

### First Year Examinations

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>529-2001-02L</td>
<td>Chemistry I</td>
<td>O</td>
<td>4</td>
<td>2V+2U</td>
<td>J. Cvengros, J. E. E. Buschmann, P. Funck, E. C. Meister, R. Verel</td>
</tr>
</tbody>
</table>

**Abstract**
General Chemistry I: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium.

**Objective**
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.

**Content**
1. Stoichiometry
   - Amount of substance and mass. Composition of chemical compounds. Reaction equation. Ideal gas law.
2. Atoms
4. Basics of chemical thermodynamics
   - System and surroundings. Description of state and change of state of chemical systems.
5. First law of thermodynamics
6. Second law of thermodynamics
   - Entropy. Change of entropy in chemical systems and universe. Reaction entropy.
7. Gibbs energy and chemical potential.
9. Chemical equilibrium

**Lecture notes**
Online-Skript mit durchgerechneten Beispielen.

**Literature**
Catherine Housecroft, Edwin Constable, CHEMISTRY: AN INTRODUCTION TO ORGANIC, INORGANIC AND PHYSICAL CHEMISTRY, 3. Auflage, Prentice Hall, 2005.(englisch)

**Taught competencies**

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
|                                         | Decision-making | assessed |
|                                         | Media and Digital Technologies | not assessed |
|                                         | Problem-solving | assessed |
|                                         | Project Management | not assessed |
| Domain C - Social Competencies | Communication | not assessed |
|                                  | Cooperation and Teamwork | not assessed |
|                                  | Customer Orientation | not assessed |
|                                  | Leadership and Responsibility | not assessed |
|                                  | Self-presentation and Social Influence | not assessed |
|                                  | Sensitivity to Diversity | not assessed |
|                                  | Negotiation | not assessed |
| Domain D - Personal Competencies | Adaptability and Flexibility | not assessed |
|                                  | Creative Thinking | assessed |
|                                  | Critical Thinking | assessed |
|                                  | Integrity and Work Ethics | not assessed |
|                                  | Self-awareness and Self-reflection | not assessed |
|                                  | Self-direction and Self-management | assessed |

| 401-0251-00L | Mathematics I | O | 6 | 4V+2U | F. Da Lio |

**Abstract**
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

**Objective**
Mathematics is of ever increasing importance to the Natural Sciences and Engineering. The key is the so-called mathematical modelling cycle, i.e. the translation of problems from outside of mathematics into mathematics, the study of the mathematical problems (often with the help of high level mathematical software packages) and the interpretation of the results in the original environment.

The goal of Mathematics I and II is to provide the mathematical foundations relevant for this paradigm. Differential equations are by far the most important tool for modelling and are therefore a main focus of both of these courses.
1. Single-Variable Calculus:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

2. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

3. Ordinary Differential Equations:
- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

4. Genetics:
- Evolution of genomes
- Origin & evolution of eukaryotes
- Origin & evolution of viruses
- Origin & evolution of prokaryotes

5. Ordinary Differential Equations:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

6. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

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- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

8. Genetics:
- Evolution of genomes
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- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

10. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

11. Ordinary Differential Equations:
- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

12. Genetics:
- Evolution of genomes
- Origin & evolution of eukaryotes
- Origin & evolution of viruses
- Origin & evolution of prokaryotes

13. Ordinary Differential Equations:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

14. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

15. Ordinary Differential Equations:
- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

16. Genetics:
- Evolution of genomes
- Origin & evolution of eukaryotes
- Origin & evolution of viruses
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17. Ordinary Differential Equations:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

18. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

19. Ordinary Differential Equations:
- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

20. Genetics:
- Evolution of genomes
- Origin & evolution of eukaryotes
- Origin & evolution of viruses
- Origin & evolution of prokaryotes

21. Ordinary Differential Equations:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

22. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

23. Ordinary Differential Equations:
- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

24. Genetics:
- Evolution of genomes
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- Origin & evolution of prokaryotes

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- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

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- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.

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- Separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

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- Origin & evolution of eukaryotes
- Origin & evolution of viruses
- Origin & evolution of prokaryotes

33. Ordinary Differential Equations:
- Review of differentiation, linearity, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

34. Linear Algebra and Complex Numbers:
- Systems of linear equations, Gaussian-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, fundamental theorem of algebra.
701-0243-01L  
**Biology III: Essentials of Ecology**  
O 3 credits  2V  C. Buser Moser

**Abstract**
This introductory lecture in ecology covers basic ecological concepts and the most important levels of complexity in ecological research. Ecological concepts are exemplified using aquatic and terrestrial systems; corresponding methodological approaches are demonstrated. Threats to biodiversity and the appropriate management are discussed.

**Objective**
The objective of this lecture is to teach basic ecological concepts and the different levels of complexity in ecological research. The students should learn ecological concepts at these different levels in the context of concrete examples from terrestrial and aquatic ecology. Corresponding methods for studying the systems will be presented.

**Content**
- Einfluss von Umweltfaktoren (Temperatur, Strahlung, Wasser, Nährstoffe etc.) auf Organismen; Anpassung an bestimmte Umweltbedingungen
- Populationsdynamik: Ursachen, Beschreibung, Vorhersage und Regulation
- Interaktionen zwischen Arten (Konkurrenz, Koexistenz, Prädation, Parasitismus, Nahrungsnetze)
- Lebensgemeinschaften: Struktur, Stabilität, Sukzession
- Ökosysteme: Kompartimente, Stoff- und Energiefluss
- Biozönose: Variation, Ursachen, Gefährdung und Erhaltung
- Aktuelle Naturschutzprobleme und -massnahmen
- Evolutionäre Ökologie: Methodik, Spezialisierung, Koevolution

**Lecture notes**
Unterlagen, Vorlesungsfolien und relevante Literatur sind in Moodle abrufbar. Die Unterlagen für die nächste Vorlesung stehen jeweils spätestens am Freitagmorgen zur Verfügung.

**Literature**
- Aquatische Ökologie: Lampert & Sommer 1999, Limnökologie, Thieme, 2. Aufl., ca. Fr. 55.-
- Bohle 1995, Limnische Systeme, Springer, ca. Fr. 50.-

701-0027-00L  
**Environmental Systems I**  
O 2 credits  2V  C. Schär, N. Dubois, G. Velicer

**Abstract**
The lecture provides a science-based exploration of environmental aspects from three research fields: earth, climate, and health sciences.

**Objective**
The students are able to explain important functions of the three environmental systems, to discuss critical drivers, trends and conflicts of their use, and to compare potential solutions.

**Content**
- Einfluss von Umweltfaktoren (Temperatur, Strahlung, Wasser, Nährstoffe etc.) auf Organismen; Anpassung an bestimmte Umweltbedingungen
- Lebensgemeinschaften: Struktur, Stabilität, Sukzession
- Ökosysteme: Kompartimente, Stoff- und Energiefluss
- Biozönose: Variation, Ursachen, Gefährdung und Erhaltung
- Aktuelle Naturschutzprobleme und -massnahmen
- Evolutionäre Ökologie: Methodik, Spezialisierung, Koevolution

**Lecture notes**
Slides are provided by instructors and are accessible via moodle.

701-0029-00L  
**Environmental Systems II**  
O 3 credits  2V  A. Patt, H. Bugmann, N. Gruber

**Abstract**
The lecture provides a science-based exploration of three important environmental systems: Inland waters, forest, and food systems.

**Objective**
The students are able to explain important functions of the three environmental systems, to discuss critical drivers, trends and conflicts of their use and to compare potential solutions.

**Content**
Aquatic ecosystems and their function, water use and its impact, water pollution and water treatment, water and health, water technologies, water & energy.

Foods and agroforest systems, trends and drivers of land use changes, sustainable forest management.

**Lecture notes**
Lecture notes or other documentation are provided by instructors and accessible via moodle.

### Additional First Year Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-0839-00L</td>
<td>Informatics</td>
<td>O</td>
<td>2</td>
<td>2G</td>
<td>L. E. Fässler, M. Dahinden</td>
</tr>
</tbody>
</table>

**Abstract**
Students learn to apply selected concepts and tools from computer science for working on interdisciplinary projects. The following topics are covered: modeling and simulations, managing data with lists and tables and with relational databases, introduction to programming.

**Objective**
The students learn to
- choose and apply appropriate tools from computer science,
- process and analyze real-world data from their subject of study,
- handle the complexity of real-world data.

**Content**
1. Modeling and simulations
2. Data management with lists and tables
3. Data management with a relational database
4. Introduction to macro programming
5. Introduction to programming with Python

**Lecture notes**
All materials for the lecture are available at www.evim.ethz.ch

**Prerequisites / notice**
This course is based on application-oriented learning. The students spend most of their time working through projects with data from natural science and discussing their results with teaching assistants. To learn the computer science basics there are electronic tutorials available.

| 529-0030-00L | Laboratory Course: Elementary Chemical Techniques | O    | 3    | 6P    | A. de Mello, F. Jenny, M. H. Schroth |

**Abstract**
This practical course provides an introduction to elementary laboratory techniques. The experiments cover a wide range of techniques, including analytical and synthetic techniques (e.g. investigation of soil and water samples or the preparation of simple compounds). Furthermore, the handling of gaseous substances is practised.

**Objective**
This course is intended to provide an overview of experimental chemical methods.

The handling of chemicals and proper laboratory techniques represent the main learning targets. Furthermore, the description and recording of laboratory processes is an essential part of this course.
The classification and analysis of natural and artificial compounds is a key subject of this course. It provides an introduction to elementary laboratory techniques, and the experiments cover a wide range of analytic and synthetic tasks:
Selected samples (e.g. soil and water) will be analysed with various methods, such as titrations, spectroscopy or ion chromatography. The chemistry of aqueous solutions (acid-base equilibria and solvation or precipitation processes) is studied.
Furthermore, the preparation and handling of environmentally relevant gaseous species like carbon dioxide or nitrogen oxides is a central subject of the Praktikum.

Lecture notes
The script will be published on the web.
Details will be provided on the first day of the semester.

Literature
A thorough study of all script materials is requested before the course starts.

Prerequisites / notice
Safety concept: https://chab.ethz.ch/studium/bachelor1.html

751-0801-00L Fundamentals of Microscopy and Plant Biology O 1 credit 1V+2G E. B. Truernit

Objective
Teaching of basic knowledge in microbiology.

Content
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function, Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Lecture notes
Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms

Literature

752-4001-00L Microbiology O 2 credits 2V M. Ackermann, M. Schuppler, J. Vorholt-Zambelli

Abstract
Teaching of basic knowledge in microbiology with main focus on Microbial Cell Structure and Function. Molecular Genetics, Microbial Growth, Metabolic Diversity, Phylogeny and Taxonomy, Prokaryotic Diversity, Human-Microbe Interactions, Biotechnology.

Objective
Teaching of basic knowledge in microbiology.

Content

Lecture notes
Die Behandlung der Themen erfolgt auf der Basis des Lehrbuchs Brock, Biology of Microorganisms

Literature

401-0624-00L Mathematics IV: Statistics O 4 credits 2V+1U J. Ernest

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for practitioners in natural sciences. The concepts will be illustrated with some real data examples and applied using the statistical software R.
Objective
Capacity to learn from data; good practice when dealing with data and recognizing possible fraud in statistics; basic knowledge about the laws of randomness and stochastic thinking (thinking in probabilities); application of simple methods in inferential statistics (e.g., several hypothesis tests will be introduced), i.e. also using the statistical software R. The lecture will be held in German.

Content

Lecture notes
Ausführliches Skript zur Vorlesung ist erhältlich.

Literature

Prerequisites / notice
Die Übungen (ca. die Hälfte der Kontakttunden; einschließlich Computerübungen) sind ein wichtiger Bestandteil der Lehrveranstaltung.

Voraussetzungen: Mathematik I, II

>>> Examination Block 2

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0071-00L</td>
<td>Mathematics III: Systems Analysis</td>
<td>O</td>
<td>4</td>
<td>2V+1U</td>
<td>L. Brunner, R. Knutti, S. Schemm, H. Wernli, P. Zschenderlein</td>
</tr>
</tbody>
</table>

Abstract
The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Objective
Learning and applying concepts (models) and quantitative methods to address concrete problems of environmental relevance.

Content
- Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

Lecture notes
Overhead slides will be made available through the course website.

Literature


<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0023-00L</td>
<td>Atmosphere</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>E. Fischer, T. Peter</td>
</tr>
</tbody>
</table>

Abstract
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Objective
Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

Content
Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Lecture notes
Written information will be supplied.

Literature

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0501-00L</td>
<td>Pedosphere</td>
<td>O</td>
<td>3</td>
<td>2V</td>
<td>R. Kretzschmar</td>
</tr>
</tbody>
</table>

Abstract
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties are explained and illustrated by numerous examples.

Objective
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

Content
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, soil formation, principles of soil classification, global soil regions, physical soil properties and functions, chemical soil properties and functions, soil fertility, land use and soil degradation.

Lecture notes
Polybook


Prerequisites / notice
Prerequisites: Basic knowledge in chemistry, biology and geology.

Additional Compulsory Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0033-00L</td>
<td>Laboratory Course in Physics for Students of Environmental Sciences</td>
<td>O</td>
<td>2</td>
<td>4P</td>
<td>M. Männich, A. Biland, N. Gruber</td>
</tr>
</tbody>
</table>

Abstract
Learning with the basic principles of scientific experimentation. By performing experiments in different fields of experimental physics the students will learn the usage of measurement instruments as well as the correct analysis and assessment of the measurements. Physics as a personal experience will play an important role in it.

No registration required via myStudies. For further information visit: https://iap.phys.ethz.ch

Only students from 3th Semester BSc Environmental Sciences on are admitted to this lecture.

Problems of the environment and sustainable development are complex from a scientific as well as from an ethical point of view. The reader and additional lecture material and exercises will be posted on Moodle.

Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and future environmental policy challenges. Students will learn about the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy. The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

Enrollment not in MyStudies but at https://www.lehrbetrieb.ethz.ch/laborpraktika.

This is a compulsory course in the social sciences and humanities in the second year of the BA Environmental sciences. For 2 ECTS-credits, all written tasks that are distributed during the course need to be solved.

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0707-00L</td>
<td>Analysing Arguments in Science and Ethics</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>C. J. Baumberger</td>
</tr>
</tbody>
</table>

This lecture was offered until spring semester 17 under the title: "Analysing Texts". Students who completed this lecture already are not allowed to earn credits for this lecture again.

Abstract
Problems of the environment and sustainable development are complex from a scientific as well as from an ethical point of view. Addressing them requires the ability to deal with arguments. This course provides basic knowledge and methods for reconstructing, analysing and evaluating arguments. We exercise and improve these abilities by using examples from science, ethics and political debates.

Objective
Students acquire basic knowledge and methods for analyzing arguments. They are able to apply these methods to complex arguments concerning scientific and ethical questions about the environment and sustainable development, and to construct themselves arguments and apply them successfully. Moreover, they are able to evaluate the contribution of arguments to controversial debates with the help of rules. Students acquire thereby a crucial skill for Critical Thinking, which aims at responsible argumentation, communication and action.

Content
In the sciences as well as in public discussions or in our everyday life, we try to convince others or to achieve consensus in matters of disagreement. We do this with the help of arguments. But what are the criteria for arguments to be convincing and for claims to be clear? And how do we expediently feed arguments into a debate? How can we identify and avoid fallacies in reasoning? How do we analyse and define concepts? This course provides basic knowledge of conceptual analysis and argumentation theory as well as methods for identifying, reconstructing and evaluating claims and arguments. Its focus is on systematically addressing the following two questions:

What do you mean? How do you know? The first question aims at a better understanding of the claim in question, the second at assessing the reasons that support or undermine the claim. We exercise and improve the abilities to address these questions by using texts on scientific and ethical questions concerning the environment and sustainable development. The course provides thus crucial skills for Critical Thinking, which aims at responsible argumentation, communication and action.

Lecture notes
Handouts will be available.

Literature

Prerequisites / notice
This is a compulsory course in the social sciences and humanities in the second year of the BA Environmental sciences. For 2 ECTS-credits, all written tasks that are distributed during the course need to be solved.

701-0747-00L Environmental Policy of Switzerland ||| 0 ||| 3 credits ||| 2G ||| E. Lieberherr

Number of participants limited to 130. Priority is given to the target group: Bachelor Study programme Environmental Sciences until September 27th, 2021.

Abstract
This course presents the basics of public policy analysis and the specific characteristics of Swiss environmental policy. Policy instruments, actors and processes are addressed from a political science perspective both theoretically as well as by means of current Swiss environmental policy examples.

Objective
Beyond acquiring basic knowledge about public policy analysis, this course teaches students how to analytically address current and concrete questions of environmental policy. Through exercises the students learn about political science concepts and frameworks as well as real-life political decision-making processes. The well-grounded examination of complex political conflict situations is an important precondition for the entry into the (environmental policy) workforce or a future research career.

Content
The processes of change, overuse or destruction of the natural environment through humans have historically placed high demands on social and political institutions. In the interplay between the environment, society and economy, the environmental policy field encompasses the sum of public measures that have the goal to eliminate, reduce or avoid environmental degradation. The course systematically presents the basics of environmental policy instruments, actors, programs and processes as well as their change over time. Invited practitioners will provide us with insight regarding the current developments in forest, water and spatial planning policies. A key aspect is the distinction between politics and political science and specifically environmental policy.

Lecture notes
The reader and additional lecture material and exercises will be posted on Moodle.

Literature
The detailed semester program (syllabus) is made available to the students at the beginning of the semester. During the lecture we will work with Moodle and eduApp. We ask that all students register themselves on these platforms before the lecture and to bring a laptop, tablet or smartphone to class, so that you can complete exercises using Moodle and eduApp.
### Taught competencies

| Domain A - Subject-specific Competencies | Concepts and Theories | assessed |
| Domain B - Method-specific Competencies | Analytical Competencies | assessed |
| Domain C - Social Competencies | Sensitivity to Diversity | assessed |
| Domain D - Personal Competencies | Critical Thinking | assessed |
| | Self-direction and Self-management | assessed |

---

### Principles of Economics

**Title**
Information about environmental management and environmental management systems, general methods and principles.

**Abstract**
This course introduces basic economic concepts and theories. Beginning with microeconomics, the course starts with the topics of supply and demand, markets, and behavioral economics before moving on to the key macroeconomic concepts of national accounts, the labor market, trade, and monetary policy.

**Objective**
After successful completion of the course you will be able to:
- Describe the basic micro- and macroeconomic problems and theories.
- Introduce economic reasoning appropriately to a given topic.
- Evaluate economic measures.

**Content**
Households, firms, supply and demand: How are household preferences and consumption patterns formed? How does a household react to price changes? How are goods prices formed? At what prices are companies willing to offer goods? How do we make economic decisions?

Markets: What is "perfect competition" and how does a competitive market work? Are monopolies always a bad thing? How can the state influence the market?

Market failure: What happens when prices give wrong signals?

Labour market: How do supply and demand work in the labour market? What influences unemployment?

National accounts: How big is the Swiss economy?

Foreign trade: Why do countries trade with each other? What are the consequences for the domestic market?

Money and inflation: What exactly is money? How does money creation work and what happens when there is too much (or too little) money on the market?

Students will be asked to apply these concepts to issues in their own field of study and to current issues in society. This goal will be achieved through participation in exercises, class discussions and reading material from current media. By the end of the course, students should be able to apply economic analysis confidently and independently.

**Lecture notes**
no script available

**Literature**

**Prerequisites / notice**
Sie brauchen keine Vorkenntnisse, um dem Kurs zu folgen.

---

### Environmental Law

**Title**
Only for Environmental Sciences BSc.

**Number of participants limited to 75**
Students who have attended and passed the course unit 851-0741-00L in the spring semester may not attend this course unit (851-0738-04L) again and can't credited it.

**Abstract**
Environmental law regulates the protection of human beings and their environment, such as animals, plants, habitats, soil, waters and air. It plays an increasing role in relation to public and private projects. The lecture gives an overall view of Swiss environmental law. Specific subjects will be dealt with in more detail based on case studies and group work.

**Objective**
The students are able:
- to apply environmental law in a specific case.
- to explain in which cases the basic principles and the particular instruments of environmental law apply.
- to identify the shortcomings of environmental law and the legislative needs in this regard.
- to describe the tasks and competencies of environmental scientists compared to those of lawyers.

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### Electives

#### Module Economics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>151-0757-00L</td>
<td>Environmental Management</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>R. Züst</td>
</tr>
</tbody>
</table>

**Abstract**
An environmental management system has the objective to continuously improve the environmental performance of the activities, products and services of a company. The company has to introduce different management procedures. The goal of this lecture is to provide basics and specific procedure to implement the environmental dimension in the planning and decision making processes of an organisation.

**Objective**
Overview on environmental management and environmental management systems, general methods and principles.

**Content**
- Introduction to environmental management / environmental management systems, energy and material flows; economical and ecological problems in industry; characterisation of an enterprise (incl. management handbook); structur and contents of an environmental management system; overview on the ISO 14001 ff. series; methods for environmental evaluation and assessment; integrated management systems; planning methodology and life-cycle-design design; planning exampl

**Lecture notes**
Information about environmental management and environmental management systems will be provided by a CD or mail.
Discovering Management offers an introduction to the field of business management and entrepreneurship for engineers and natural scientists. By taking this course, students will enhance their understanding of management principles and the tasks that entrepreneurs and managers deal with. The course consists of theory and practice sessions, presented by a set of area specialists at D-MTEC.

**Objective**
The general objective of Discovering Management is to introduce students into the field of business management and entrepreneurship.

In particular, the aims of the course are to:
1. Broaden understanding of management principles and frameworks.
2. Advance insights into the sources of corporate and entrepreneurial success.
3. Develop skills to apply this knowledge to real-life managerial problems.

The course will help students to successfully take on managerial and entrepreneurial responsibilities in their careers and/or appreciate the challenges that entrepreneurs and managers deal with.

**Content**
The course consists of a set of theory and practice sessions, which will be taught on a weekly basis. The course will cover business management knowledge in corporate as well as entrepreneurial contexts.

The course consists of three blocks of theory and practice sessions: Discovering Strategic Management, Discovering Innovation Management, and Discovering HR and Operations Management. Each block consists of two or three theory sessions, followed by one practice session where you will apply the theory to a case.

The theory sessions will follow a "lecture-style" approach and be presented by an area specialist within D-MTEC. Practical examples and case studies will bring the theoretical content to life. The practice sessions will introduce you to some real-life examples of managerial or entrepreneurial challenges. During the practice sessions, we will discuss these challenges in depth and guide your thinking through team coaching.

Through small group work, you will develop analyses of each of the cases. Each group will also submit a "pitch" with a clear recommendation for one of the selected cases. The theory sessions will be assessed via a multiple-choice exam.

**Lecture notes**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

These course materials will form the point of departure for the lectures, class discussions and team work.

**351-0778-00L Discovering Management**

**Abstract**
Discovering Management (Exercises) thus focuses on developing the skills and competences to apply management theory to a real-life exercise from practice.

**Objective**
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

**Content**
Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of their choice, using your insights from Discovering Management.

**Literature**
A list with literatures and links will be provided.

Delivery of a case study, worked out in groups. Language: Teaching in English on request.

**Prerequisites / notice**
Students following this course should also be enrolled for course 351-0778-00L, "Discovering Management".

**351-0778-01L Discovering Management (Exercises)**

**Objective**
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

**Content**
Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of their choice, using your insights from Discovering Management.

**3G**

**Literature**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

**Prerequisite:** Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

**Abstract**
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

**Domain D - Personal Competencies**

**4G**

**Domain B - Method-specific Competencies**

**Domain C - Social Competencies**

**Domain A - Subject-specific Competencies**

**Assessed**

**Taught competencies**

**Literature**
All course materials (readings, slides, videos, and worksheets) will be made available to inscribed course participants through Moodle.

**Prerequisite:** Participation and successful completion of the module Discovering Management (351-0778-00L) is mandatory.

**Abstract**
This course is offered complementary to the basis course 351-0778-00L, "Discovering Management". The course offers an additional exercise.

**Objective**
The general objective of Discovering Management (Exercises) is to complement the course "Discovering Management" with one larger additional exercise.

**Content**
Students who are enrolled for "Discovering Management Exercises" are asked to write an essay about a particular management issue of their choice, using your insights from Discovering Management.

**4G**

**Domain D - Personal Competencies**

**Assessed**

**Taught competencies**

**Data:** 14.12.2021 12:41

**Autumn Semester 2021**

**Page 2035 of 2152**
In the first part of the semester, Prof. Volker Hoffmann and Dr. Johannes Meuer will share his insights on corporate sustainability with you through a series of lectures. They introduce you to a series of critical thinking exercises and build a foundation for your group work. In the second part of the semester, you participate in four of tracks in which SusTec researchers will coach your groups through a seven-step program. Our ambition is that you improve your analytic and organizational skills and that you can confidently stand up for corporate sustainability in a professional setting. You will share the final product of your work with fellow students in a final puzzle session at the end of the semester.

http://www.sustec.ethz.ch/teaching/lectures/corporate-sustainability.html

Presentation slides will be made available on moodle prior to lectures. Literature recommendations will be distributed during the lecture.

TEACHING FORMAT / ATTENDANCE: Please note that we aim to offer you the course in-class and online, but at this point we cannot guarantee that a purely online participation is possible. Irrespective of the format (in-class or online), the course includes several mandatory sessions that participants must attend to successfully earn credit points.

<table>
<thead>
<tr>
<th>363-0537-00L</th>
<th>Resource and Environmental Economics</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>L. Bretschger</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.</td>
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<tr>
<td><strong>Content</strong></td>
<td>The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In the final chapter, we consider international environmental problems and in particular climate change and climate policy.</td>
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<thead>
<tr>
<th>363-1109-00L</th>
<th>Introduction to Microeconomics</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>M. Wörter, M. Beck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>This course is only for students enrolled in a Bachelor’s degree programme. Students enrolled in a Master’s degree programme may attend “Principles of Microeconomics” (LE 363-0503-00L) instead.</td>
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<tr>
<td><strong>Objective</strong></td>
<td>The course introduces basic principles, problems and approaches of microeconomics. It describes economic decisions of households and firms, and their coordination through perfectly competitive markets.</td>
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<tr>
<td><strong>Content</strong></td>
<td>They acquire the ability to apply these models in the interpretation of real world economic contexts.</td>
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<tr>
<td><strong>Lecture notes</strong></td>
<td>Market, budget constraint, preferences, utility function, utility maximisation, demand, technology, profit function, cost minimisation, cost functions, perfect competition, information and communication technologies</td>
<td></td>
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</tr>
<tr>
<td><strong>Literature</strong></td>
<td>Course material in e-learning environment <a href="https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php">https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php</a></td>
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</tr>
<tr>
<td><strong>Prerequisites / notice</strong></td>
<td>This course &quot;Einführung in die Mikroökonomie&quot; (363-1109-00L) is intended for Bachelor students and LE 363-0503-00 &quot;Principles of Microeconomics&quot; for Master students.</td>
<td></td>
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</tbody>
</table>
Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: not assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-presentation and Social Influence: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

851-0626-01L
International Aid and Development
Number of participants limited to 60

Prerequisites: Basic knowledge of economics

Abstract
The course gives economic and empirical foundations for a sound understanding of the instruments, prospects and limitations of international development aid.

Objective
Students have a theoretically and empirically sound understanding of the prospects and limitations of international development aid. Students are able to critically discuss the various aid instruments of bi-and multilateral donors and NGOs.

Content
Introduction to the Determinants of Underdevelopment; History of Aid; Aid and Development: Theories and Empirics; Political Economy of Aid; Experience and Impact of Aid; New Instruments of Aid; e.g. Micro-Finance, Budget-Support; Fair-Trade.

Literature
Articles and book abstracts will be uploaded to a course website.
Dieser Kurs wird aufgrund der immer noch prekären Covid-19-Lage voraussichtlich online durchgeführt. Alle Studierenden, die den Kurs via mystudies belegt haben, werden rund eine Woche vor Kursbeginn über die aktuelle Situation informiert.


Tipp: Lesen Sie zuerst genau die Übungsfragen für das zu studierende Buchkapitel (https://ib.ethz.ch/teaching/pwgrundlagen.html) und erst danach das betreffende Kapitel. Sie wissen dann beim Lesen schon vorweg, auf was Sie besonders genau schauen sollten.


Übungsfragen und ein Glossar finden Sie hier: https://ib.ethz.ch/teaching/pwgrundlagen.html

Leistungskontrollen
a) Erster Test (12.11.2021, 14:15–15:00)

b) Zweiter Test (17.12.2021, 14:15–15:00)

Ergebnisse und Auswertung: https://ib.ethz.ch/teaching/pwgrundlagen.html

Kreditpunkte
4 ECTS-Punkte (Zeitaufwand insgesamt ca. 120 Arbeitsstunden)

Lecture notes

Pro Kurseinheit (Woche) sind ca. 30–40 Seiten zu lesen. Für einzelne Kurseinheiten müssen Sie etwas mehr lesen (zwei Buchkapitel, ca. 60–80 Seiten insgesamt). Es lohnt sich also, bereits von Anfang des Kurses an ein wenig «auf Vorrat» zu lesen.


Weitere Lehrmaterialien finden Sie auf: http://www.ib.ethz.ch/teaching/pwgrundlagen

Das Buch „Einführung in die Politikwissenschaft“ von Thomas Bernauer, Detlef Jahn, Patrick Kuhn und Sylvia Kritzinger (5. Auflage, Nomos, 2022) ist momentan in Bearbeitung. Deshalb erhalten die Studierenden die Entwurfsversion elektronisch (via Moodle) und müssen das Buch nicht kaufen.

Für die beiden Tests dürfen Sie vier Seiten Notizen benutzen (zwei Blätter beidseitig beschrieben). Elektronisch bedruckte Notizblätter werden ausnahmslos nicht zur Prüfung zugelassen.

Die Teilnahme am Tutorat ist integraler Bestandteil des Kurses, und der im Tutorat behandelte Stoff ist Bestandteil der Leistungskontrollen.

Prerequisites / notice

Sie müssen die zugewiesenen Buchkapitel vor der jeweiligen Kurseinheit gründlich lesen und Fragen notieren, damit wir effizient vorankommen. Pro Kurseinheit (Woche) sind ca. 30–40 Seiten zu lesen. Für einzelne Kurseinheiten müssen Sie etwas mehr lesen (zwei Buchkapitel, ca. 60–80 Seiten insgesamt). Es lohnt sich also, bereits von Anfang des Kurses an ein wenig «auf Vorrat» zu lesen.

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Für jeden der beiden Tests erhalten Sie bei einer Note von 4 oder mehr einen Bonus für die Basisprüfung. Sie können sich also durch das Absolvieren der beiden Tests in der Basisprüfung verbessern bzw. ein Polster erwerben.
The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

The course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

This course provides an introduction to psychological research and modelling, focusing on cognitive psychology and the psychological experiment. Participants learn to formulate problems for psychological investigation and apply basic forms of psychological experiment.

Students are able to:
- describe the areas, concepts, theories, methods and findings of psychology.
- differentiate scientific psychology from "everyday" psychology.
- structure the conclusions and significance of an experiment according to a theory of psychology.
- formulate a problem for psychological investigation.
- apply basic forms of psychological experiment.

Participants learn to formulate problems for psychological investigation and apply basic forms of psychological experiment.

To facilitate your planning, the course is organized in terms of weekly units.

Module Individual Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-0721-00L</td>
<td>Psychology</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>R. Hansmann, A. Bearth, M. Siegrist</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>Objective</td>
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<td></td>
<td>Students are able to</td>
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<td>- describe the areas, concepts, theories, methods and findings of psychology.</td>
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<td>- differentiate scientific psychology from &quot;everyday&quot; psychology.</td>
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<td>- structure the conclusions and significance of an experiment according to a theory of psychology.</td>
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<td>- formulate a problem for psychological investigation.</td>
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<td>- apply basic forms of psychological experiment.</td>
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<tr>
<td>701-0785-00L</td>
<td>Introduction to Science Communication (University of W Zurich)</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>M. Schäfer</td>
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<tr>
<td></td>
<td>Abstract</td>
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<td></td>
<td>The course gives an introductory overview in research questions, theoretical perspectives and empirical results of science communication and environmental communication. They will be illustrated by concrete examples and via lectures from external guests.</td>
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<td></td>
<td>Objective</td>
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<tr>
<td></td>
<td>Goals: Learning to understand structures and processes of environmental and science communication, becoming more sensitive for problems of science public relations, getting an insight into public debates about environmental issues.</td>
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<td>Methods: invitation of media practitioners and experts, discussions, lectures on key theoretical concepts of communication.</td>
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<td>Topics: Concrete communication instruments like media conferences, theoretical perspectives of public relations, basic principles and examples of information campaigns, environment and science as media topics, functions and structures of science communication, relations between science, media and politics.</td>
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</tbody>
</table>
I. Introduction
- Topics: Environment, Science, Risks, Media
- Forms, Functions, Effects of Public and Mass Communication

II. Stakeholders and their Public Relations Efforts
- Public Relations and Science PR: Theoretical Perspectives, Instruments

III. Science and Environmental Issues in the Media
- Forms and Functions of Science Journalism
- Problems of Selection, Interpretation, Quality
- Media Content Analysis
- Online Communication

IV. Uses and Effects of Science and Environmental Communication
- Extent of Media Use
- Effects on Knowledge, Risk Perceptions, Environmental Attitudes
- Effects on Science itself

Lecture notes
- Literature and powerpoint presentations will be provided on the OLAT platform.

Literature

Prerequisites / notice
- The Sustainable Development Goals Book Club
- W 2 credits
- B. B. Pearce, J. Ghazoul

Abstract
- The Sustainable Development Goals Book Club is a colloquium for Bachelor students within and outside of Department of Environmental Systems Science centered around the discussion of themes from a single book, with the aim of fostering interdisciplinary, intellectual and critical exploration of the scientific and societal complexities related to the Sustainable Development Goals.

Objective
- The aims of this course are to:
  - Create an interdisciplinary approach to understanding key concepts of sustainable development and the SDGs
  - Create solidarity through a cultural of intellectual exchange at ETH Zurich
  - Create a common object of intellectual reference for students with different disciplinary interests to enable diverse ways and modes of thinking

Content
- The course is similar to 701-0019-00L Readings in Environmental Thinking with the following differences:
  - Targeted at Bachelor's students (especially first and second year, but open to all) within and outside of the department.
  - All participating students will read one book whose themes will be the basis for discussions.
  - These discussions, taking place both online and in-person, will be moderated by the main lecturers of the course and discussed by additional professors from within and outside of D-USYS.
  - Each discussion will be based on a chapter of a book, always linked to a particular aspect of the SDGs.
  - The modes of discussion will vary in length and form, ranging from the traditional, sit-down meeting, to a Twitter book club format (as already pioneered and popularized by author Robert MacFarlane).
  - Both students and professors will lead the discussions alternatively.
  - Each discussion session will result in a visual output or another shareable output that will be developed by a student or group of students.

Literature
- TBD
- Could be one of the books already used in 701-0019-00L Readings in Environmental Thinking (Silent Spring, The Sand County Almanac, Collapse...etc.)
- Other possibilities:
  - Thinking in systems
  - Limits to Growth
  - Operating Manual for Spaceship Earth
  - Small is Beautiful
  - For the Common Good
  - Factfulness
  - The Prize: The Epic Quest for Oil, Money and Power (history of the global petroleum industry from 1850s-1990)

Prerequisites / notice
- 701-0903-00L Readings in Environmental Thinking
- 2 credits
- W 2 credits
- B. B. Pearce

Abstract
- The ETH Sustainable Development Goals Book Club is a colloquium for Bachelor students within and outside of Department of Environmental Systems Science centered around the discussion of themes from a single book, with the aim of fostering interdisciplinary, intellectual and critical exploration of the scientific and societal complexities related to the Sustainable Development Goals.

Objective
- Introduction in consumer research. The following aspects will be emphasized in the course: Consumer decision making, individual determinants of consumer behavior, environmental influences on consumer behavior, influencing consumer behavior
### Module Humanities

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<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-0703-00L</td>
<td>Environmental Ethics</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>A. Deplazes Zemp</td>
</tr>
</tbody>
</table>

#### Abstract
The pressing environmental challenges of today demand a critical reflection. Ethics is an important tool for doing so. This lecture introduces the basics of ethics and provides in-depth knowledge of environmental ethics and its debates. This theoretical background will be applied and critically reflected using examples of current environmental challenges.

#### Objective
On completion of this lecture, you have acquired the ability to identify, analyze, critically reflect and resolve ethical challenges in general and specifically regarding the environment. You know basic concepts, positions and lines of argumentation from the debate in environmental ethics, which you have applied and discussed in smaller exercises.

#### Content
- Introduction to general and applied ethics.
- Overview and discussion of ethical theories relevant to address environmental challenges.
- Familiarization with various basic standpoints within environmental ethics.
- Cross-section topics, such as sustainability, intergenerational justice, protection of species, etc.
- Practicing of newly acquired knowledge in smaller exercises.

#### Lecture notes
Presentation slides of the individual sessions will be distributed, including the most important theories and keywords; extended reading lists.

#### Literature
- Andrew Light/Holmes Rolston III, Environmental Ethics. An Anthology, 2003
- John O'Neil et al., Environmental Values, 2008
- Konrad Ott/Jan Diersk/Lieske Vogel-Kleschin, Handbuch Umweltethik, 2016

Generel introductions:
- Marcus Düwell et al. (Hrg.), Handbuch Ethik, 2. Auflage, Stuttgart (Metzler Verlag), 2006
- Johann S. Ach et al. (Hrg.), Grundkurs Ethik 1. Grundlagen, Paderborn (mentis) 2008

#### Prerequisites / notice
The procedure for accumulating CP will be explained at the start of term.

### Creditable Language Courses

**Of the listed English language courses, a maximum of 2 CP can be credited.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>851-0832-10L</td>
<td>Advanced English for Academic Purposes (C1-C2)</td>
<td>W</td>
<td>2</td>
<td>2G</td>
<td>University lecturers</td>
</tr>
</tbody>
</table>

**Course fees:**

**Registration dates:**

#### Abstract
This course is designed for Bachelor’s and Master’s students from all disciplines who wish to improve their English from C1 towards C2 level and train their language skills at mastery level. Selected academic English features are included to add value to the course to meet standard entrance requirements by leading universities and colleges worldwide.

#### Objective
Participants should already have reached C1 level (advanced) as defined in the Common European Framework of Reference for Languages (CEFR). The course is also open to participants whose level is above C1.

The course aims to train and develop linguistic skills at mastery level, with a focus on formal and informal academic lexicon, on listening and oral communication skills, and on increasing fluency, accuracy, and complexity of spoken language. Students will work on writing well-structured descriptive texts and argumentative essays, with the aim of fulfilling the language requirements for study at an English-speaking university or following university Master’s courses held in English.

### Highly recommended Natural Science and Technical Electives

#### For the Specialization in Biogeochemistry

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-0225-00L</td>
<td>Organic Chemistry</td>
<td>W</td>
<td>2</td>
<td>2V+1U</td>
<td>K. McNeill</td>
</tr>
</tbody>
</table>

#### Abstract
Basics of Organic Chemistry. Reaction mechanisms in organic chemistry (substitutions, additions, eliminations, condensations, electrophilic aromatic substitution and NMR spectroscopy)

#### Objective
This course builds on General Chemistry I and II.

The students will learn the basic reaction mechanisms in organic chemistry. They will be able to understand and formulate simple organic reactions.

#### Content
Descriptive chemistry of functional groups (alkyl halides, aikens, aromatic systems, carbonyls).

#### Literature
Carsten Schmuck, Basisbuch Organische Chemie, Pearson

#### Prerequisites / notice
Der Stoff der Basischemie wird vorausgesetzt.

<table>
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<tr>
<th>Number</th>
<th>Title</th>
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</tr>
</thead>
<tbody>
<tr>
<td>752-0100-00L</td>
<td>Biochemistry</td>
<td>W</td>
<td>2</td>
<td>2V</td>
<td>C. Frei</td>
</tr>
</tbody>
</table>

#### Abstract
Basic knowledge of enzymology, in particular the structure, kinetics and chemistry of enzyme-catalysed reaction in vitro and in vivo. Biochemistry of metabolism: Those completing the course are able to describe and understand fundamental cellular metabolic processes.

#### Objective
Students are able to understand
- the structure and function of biological macromolecules
- the kinetic bases of enzyme reactions
- thermodynamic and mechanistic basics of relevant metabolic processes

Students are able to describe the relevant metabolic reactions in detail.
Introduction, basics, composition of cells, biochemical units, repetition of relevant organic chemistry
Structure and function of proteins
Carbohydrates
Lipids an biological membranes
Enzymes and enzyme kinetics
Catalytic strategies
Metabolism: Basic concepts and design. Repetition of basic thermodynamics
Glycolysis, fermentation
The citric acid cycle
Oxidative phosphorylation
Fatty acid metabolism

Horton et al. (Pearson) serves as lecture notes.

Basic knowledge in biology and chemistry is a prerequisite.

For the Specialization in Environmental Biology

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>227-0399-10L</td>
<td>Physiology and Anatomy for Biomedical Engineers I</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Wyss</td>
</tr>
</tbody>
</table>

Abstract
This course offers an introduction into the structure and function of the human body, and how these are interlinked with one another. Focusing on physiology, the visualization of anatomy is supported by 3D-animation, Computed Tomography and Magnetic Resonance imaging.

Objective
To understand basic principles and structure of the human body in consideration of the clinical relevance and the medical terminology used in medical work and research.

Content
- The Human Body: nomenclature, orientations, tissues
- Musculoskeletal system, Muscle contraction
- Blood vessels, Heart, Circulation
- Blood, Immune system
- Respiratory system
- Acid-Base-Homeostasis

Lecture notes
Lecture notes and handouts

Literature
Silbernagl S., Despopoulos A. Color Atlas of Physiology; Thieme 2008
Faller A., Schuenke M. The Human Body; Thieme 2004
Netter F. Atlas of human anatomy; Elsevier 2014

For the Specialization in Forest and Landscape

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0266-00L</td>
<td>Introduction to Dendrology</td>
<td>W</td>
<td>3 credits</td>
<td>3P</td>
<td>A. Rudow, M. Ibrahim</td>
</tr>
</tbody>
</table>

Abstract
Woody plants are important elements of forest ecosystems and landscapes. The course gives an introduction to dendrology as well as to the identification of native tree and shrub species. It is a highly recommended course for the BSc specialization of Forest and Landscape and provides the basic requirements for the consecutive course Woody Plants of Central Europe in the spring semester.

Objective
Knowledge of selected native tree and shrub species. Understanding of biological and ecological relations by means of in situ observation of woody plants. Differentiated view on forest ecosystems.

Content
Introduction to dendrology on the basis of concrete examples. Emphasis on identification of tree and shrub species (80 frequent tree and shrub species) and on the understanding of tree structure (morphology of woody plants). The illustrating way of presentation and the relations between different scale levels (organ, individual, stand, ecosystem) provide an attractive insight into forest and landscape topics as well as into environmental biology.

Lecture notes
Rudow, A., 2020: Dendrologie 1 - Folien (in German).

Literature
Rudow, A., 2011: eBot Dendrologie (Betaverion). E-learning-Tool for the support of dendrology courses at ETHZ (application integrated in eBot, in German).

Prerequisites / notice
Half of the course will be held in form of excursions and practical training in the forest (ETH Hönggerberg). Besides that 4 half day excursions (Zurich and surroundings, on weekends, dates by arrangement). Weatherproof clothes are presupposed.

The course provides the basic knowledge for the advanced course 701-0316-00L Woody plants of Central Europe (Dendrology 2)
The course shall particularly elucidate the cross section of Agro- and Food Sciences in the context of important global problems to be solved. Furthermore the students in the first year of studies shall be given some insight and outlook supporting the development of their views and interests in agricultural and food sciences further.

The course is part of the block exam after the first study year. Paper copies can be used (“Open Book”) during the on-line exam, but no other means are not allowed. The course is taught in German.

Number Title Type ECTS Hours Lecturers
751-0013-00L World Food System W 4 credits 4V A. K. Gilgen, J. Baumgartner, A. Bearth, R. Finger, M. Loessner, R. Mezzenga, B. Studer
751-1311-00L Introduction to Agricultural Management W 2 credits 2V R. Finger
751-3401-00L Plant Nutrition I W 2 credits 2V E. Frossard

Abstract

Knowledge about the World Food System will be provided, based on case studies along food value chains in countries with various development stages and dependent on multiple boundary conditions. This shall generate profound understanding of the associated global challenges especially food scarcity, suboptimal diet and nutrition, food quality and safety as well as effects on the environment.

Content

Case studies on certain foods of plant and animal origin serve to demonstrate the entire food value chain from the production of raw material to processed food and its consumer relevant property functions. In doing so, important corresponding aspects for developed, emerging and developing countries are demonstrated, by use of engineering as well as natural and social science approaches.

Literature


Prerequisites / notice

Aufgrund der Grösse des verfügbaren EDV-Schulungsraumes ist die Teilnehmerzahl auf 50 Studierende beschränkt! Für die Übungen werden die Studierenden auf zwei Zeitfenster aufgeteilt. Pro Zeitfenster können maximal 25 Studierende betreut werden.
At the end of the lecture, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality. They are able to propose fertilization plans adapted for field crops growing under Swiss conditions.

A general introduction explains the needs of appropriately managing nutrients in plant production. Afterwards, we will study the physiology of plant nutrition (nutrient uptake by roots; nutrient transports in the plant; physiological roles of nutrients in the plant). Then the role of nutrients for yield formation and their effects on crop quality is dealt with. Finally, the bases of crop fertilization are taught (availability of nutrient in soil; N, P and K fertilization; different types of fertilizers).

The slides will be distributed.


http://www.tll.de/visuplant/vp_idx.htm

Objective

The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Lab and field measurements are included.

The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about classical and latest studies in plant ecophysiology and will have hands-on experiences with equipment used in plant ecophysiology.

The general theme of this course is to offer students and the interested public a deeper insight into the fundamentals of agroecology and its potential role in transforming food systems. For more information on the public lecture part of this course, please visit: https://worldfoodsystem.ethz.ch/outreach-and-events/past-events/agroecology-lectures-2021.html

Students know the elements of agroecology and are able to critically reflect on the important properties as well as benefits and trade-offs of agroecological systems and approaches. Students are able to understand and explain how the 10 elements could be implemented as guiding principles for policymakers, practitioners and other stakeholders across the food system in planning, managing and evaluating agroecological transitions. This course enables students and an interested public to engage in a lively and critical debate and to learn about scientific contributions to agroecology. Based on the knowledge gained, students are able to form a personal opinion on the role of agroecology and to reflect on the different facets and real-world applications supporting a transition towards sustainable food systems.
Organization of the lecture:
The lecture series will take place in the fall semester of ETH Zurich, starting in the week of September 20, 2021 and lasting until December 17, 2021. During this period, the lecture will take place once a week, on Tuesdays from 18:00-20:00 (CEST/CET).
Each lecture will be organized in an online format and will be set up in two parts consisting of a public and a student lecture:
At the end of the lecture series, the course will be evaluated with the students.

Public lecture part (virtually via Zoom webinar):
The public lecture (18:00-19:00 CEST/CET) will take place virtually via this Zoom webinar: https://ethz.zoom.us/j/64352765873.
While most public lectures will take one hour, the last public lecture on “Agroecology, The Way Forward”, on Tuesday, 7th December 2021, will last 90 minutes.

Student’s lecture part (exchange with course instructors online via zoom):
The student’s lecture (19:15-20:00h CEST/CET) will take place online via a normal Zoom call: https://ethz.zoom.us/j/61315399346.

For further details, please refer to the Moodle-page of this course: https://moodle-app2.let.ethz.ch/course/view.php?id=15210

Lecture notes
On the Moodle-page you can find some pre-readings for the course.

Prerequisites / notice
The course is designed as a public lecture on “Agroecology in the transition to sustainable food systems” to allow for different perspectives to be represented, heard and discussed.

751-7501-00L Animal Housing and Behaviour W 1 credit 1V J. Müller, S. Goumon

Abstract
The overall goal of this course is to provide general knowledge about the behaviour, housing and welfare of domestic animals.
Students will:
- Understand the basis of animal behaviour and how it is measured
- Acquire knowledge of housing systems and management of domestic animals
- Get a concept of animal needs and welfare

Content
BEHAVIOR
- Fundamentals of animal behavior: mechanisms, development, function and evolution
- Overview of the natural behavioural repertoire of various livestock species and the resulting needs
- Insights in behavioural studies

ANIMAL HUSBANDRY
- Fundamentals of animal husbandry
- Insight in animal transportation and slaughter

BEHAVIOR vs. ANIMAL HUSBANDRY
- Adapt the husbandry practices to livestock-specific needs
- Recurrent problems in livestock management
- Concept of animal welfare

PERFORMANCE ASSESSMENT: 1 written report (20%) + 1 final examination (80% of grade)

Lecture notes
Handouts/scripts are provided by the lecturers.

Literature
Specific literature recommendations will be provided by the lecturers as appropriate

Prerequisites / notice
This lecture is part of the Agricultural Sciences Bachelor (3rd Semester)
This course introduces basic concepts of micro- and macronutrient nutrition. Micronutrients studied include fat-soluble and water-soluble vitamins, minerals and trace elements. Macronutrients include proteins, fat and carbohydrates. Special attention is given to nutrient digestion, bioavailability, metabolism and excretion with some focus on energy metabolism.

**Domain A - Subject-specific Competencies**
- Concepts and Theories
- Techniques and Technologies

**Domain B - Method-specific Competencies**
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

**Domain C - Social Competencies**
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

**Domain D - Personal Competencies**
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

**Literature**
- Elmadfa I & Leitzmann C: Ernährung des Menschen
- Garrow JS and James WPT: Human Nutrition and Dietetics
  - Churchill Livingstone, Edinburgh, 11th rev. ed. 2005

**Soil Sciences**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0533-00L</td>
<td>Soil and Water Chemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. Kretzschmar, D. I. Christl, L. Winkel</td>
</tr>
</tbody>
</table>

**Abstract**
This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

**Objective**
1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, bioavailability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

**Content**
Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

**Lecture notes**
Lecture slides on Moodle

**Literature**
- Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.

**Prerequisites / notice**
The lecture courses Pedosphere and Hydrosphere are highly recommended.
Students are able to - characterize porous media at different scales - parameterize structural, flow and transport properties of partially-saturated porous media - quantify driving forces and resulting fluxes of water, solute, and heat in soils

Week 2: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

Week 7: Unsaturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow

Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project

Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow

Week 10: Root water uptake and transpiration

Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

Week 12: Summary of lectures; solution of old exam

Week 13: Written semester-end exam

Week 14: Short presentations of Hydrus class projects; discussion of written exam

Supplemental textbook (not mandatory) -Introduction to Environmental Soil Physics, by: D. Hillel

The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils/ near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

This introductory course starts from a descriptions of the behavior and phenomena of soils and rocks under near surface loading conditions and their key geotechnical properties. Lab and field methods for the characterization of soils, rocks and rock masses are introduced. Finally practical aspects of ground engineering, including tunneling and landslide hazards are presented.

This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts. The course consists of weekly lectures and bi-weekly exercises in groups.

This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts.


Übungen zum Gesteinsbestimmen und Lesen von geologischen, tektonischen und geotechnischen Karten, einfache Konstruktionen.

The course is based on Press & Siever book Dynamic Earth by Grotzinger et al., available to ETH students via https://link.springer.com/book/10.1007/978-3-662-48342-8

The aim of these lecture is to present the processes controlling the uptake and transport of nutrients by the plant, the assimilation of nutrients in the plant, the effect of nutrients on crop yield and quality, the role of the soil as a source of nutrients for crops, and the basic principles of fertilization of different crop types using mineral and organic fertilizers.

This course gives an overview of the basic concepts of geology and petrography and shows some links to the application of these concepts. The course consists of weekly lectures and bi-weekly exercises in groups.
At the end of the lecture, students know how mineral nutrients are taken up through roots and circulate in the plants and what their roles in plants are. They understand the importance of nutrients for yield formation and for crop product quality. They are able to propose fertilization plans adapted for field crops growing under Swiss conditions.

A general introduction explains the needs of appropriately managing nutrients in plant production. Afterwards, we will study the physiology of plant nutrition (nutrient uptake by roots; nutrient transports in the plant; physiological roles of nutrients in the plant). Then the role of nutrients for yield formation and their effects on crop quality is dealt with. Finally, the bases of crop fertilization are taught (availability of nutrient in soil; N, P and K fertilization; different types of fertilizers).

The slides will be distributed.

Schubert S 2006 Pflanzennährung Grundwissen Bachelor Ulmer UTB
Richner W. & Sinaj S., 2017. Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD 2017). Agrarforschung Schweiz 8 (6), Spezialpublikation,

http://www.tif.de/visuplant/vp_idx.htm

Methods of Statistical Data Analysis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>401-0625-01L</td>
<td>Applied Analysis of Variance and Experimental</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>L. Meier</td>
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<td></td>
<td>Design</td>
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<tr>
<td>401-0649-00L</td>
<td>Applied Statistical Regression</td>
<td>W</td>
<td>5</td>
<td>2V+1U</td>
<td>M. Dettling</td>
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</table>

**Abstract**

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Objective**

Participants will be able to plan and analyze efficient experiments in the fields of natural sciences. They will gain practical experience by using the statistical software R.

**Content**

Principles of experimental design, one-way analysis of variance, contrasts and multiple comparisons, multi-factor designs and analysis of variance, complete block designs, Latin square designs, random effects and mixed effects models, split-plot designs, incomplete block designs, two-series factorials and fractional designs, power.

**Literature**


**Prerequisites / notice**

The exercises, but also the classes will be based on procedures from the freely available, open-source statistical software R, for which an introduction will be held.

In the Mathematics Bachelor and Master programmes, the two course units 401-0649-00L “Applied Statistical Regression” and 401-3622-00L “Statistical Modelling” are mutually exclusive. Registration for the examination of one of these two course units is only allowed if you have not registered for the examination of the other course unit.

**Taught competencies**

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: assessed
- Media and Digital Technologies: assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

**401-6215-00L Using R for Data Analysis and Graphics (Part I)**

**Abstract**

The course provides the first part an introduction to the statistical software R (https://www.r-project.org/) for scientists. Topics covered are data generation and selection, graphical and basic statistical functions, creating simple functions, basic types of objects.

**Objective**

The students will be able to use the software R for simple data analysis and graphics.
The course provides the first part of an introduction to the statistical software R for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part I of the course covers the following topics:
- What is R?
- R Basics: reading and writing data from/to files, creating vectors & matrices, selecting elements of dataframes, vectors and matrices, arithmetics;
- Types of data: numeric, character, logical and categorical data, missing values;
- Simple (statistical) functions: summary, mean, var, etc., simple statistical tests;
- Writing simple functions;
- Introduction to graphics: scatter-, boxplots and other high-level plotting functions, embellishing plots by title, axis labels, etc., adding elements (lines, points) to existing plots.

The course focuses on practical work at the computer. We will make use of the graphical user interface RStudio: www.rstudio.org

Note: Part I of UsingR is complemented and extended by Part II, which is offered during the second part of the semester and which can be taken independently from Part I.

Lecture notes
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

Prerequisites / notice
The course resources will be provided via the Moodle web learning platform.
As from FS 2019, subscribing via Mystudynet should "automatically" make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=15518

401-6217-00L Using R for Data Analysis and Graphics (Part II) W 1.5 credits 1G M. Mächler

Abstract
The course provides the second part an introduction to the statistical software R for scientists. Topics are data generation and selection, graphical functions, important statistical functions, types of objects, models, programming and writing functions. Note: This part builds on "Using R... (Part I)", but can be taken independently if the basics of R are already known.

Objective
The students will be able to use the software R efficiently for data analysis, graphics and simple programming

Content
The course provides the second part of an introduction to the statistical software R (https://www.r-project.org/) for scientists. R is free software that contains a huge collection of functions with focus on statistics and graphics. If one wants to use R one has to learn the programming language R - on very rudimentary level. The course aims to facilitate this by providing a basic introduction to R.

Part II of the course builds on part I and covers the following additional topics:
- Elements of the R language: control structures (if, else, loops), lists, overview of R objects, attributes of R objects;
- More on R functions;
- Applying functions to elements of vectors, matrices and lists;
- Object oriented programming with R: classes and methods;
- Tayloring R: options
- Extending basic R: packages

Lecture notes
An Introduction to R. http://stat.ethz.ch/CRAN/doc/contrib/Lam-IntroductionToR_LHL.pdf

Prerequisites / notice
Basic knowledge of R equivalent to "Using R .. (part 1)" ( = 401-6215-00L ) is a prerequisite for this course.

The course resources will be provided via the Moodle web learning platform.
As from FS 2019, subscribing via Mystudynet should "automatically" make you a student participant of the Moodle course of this lecture, which is at https://moodle-app2.let.ethz.ch/course/view.php?id=15522

Ecology and Conservation Biology

Number Title Type ECTS Hours Lecturers
701-0305-00L Vertebrate Ecology W 2 credits 2G J. Senn, K. Bollmann

Abstract
The course covers the ecology and conservation biology of birds and mammals. Important concepts from physiology, behavioural ecology, population biology, biogeography and community ecology will be linked to applications in conservation and management. A worldwide perspective will be complemented by a focus on the Central European fauna and its dynamics.

Objective
The students are familiar with important topics in animal ecology, with an emphasis on birds and mammals. They are able to link theoretical concepts with ecological phenomena and view them against an evolutionary backdrop. They can thus appraise applied aspects of the conservation and the use of animal populations, such as the influence of larger predators on prey populations or of herbivores on vegetation, the effects of hunting, landscape change, or of other human influences on animal populations. They understand the biogeographical characteristics of the Central European vertebrate fauna and its temporal and spatial dynamics.
The course deals with a number of main topics that include feeding and resource use, spatial behaviour and migrations, reproduction, population dynamics, competition and predation, parasites and diseases, biodiversity and distributions, and dynamics of the Central European fauna. There is an emphasis on linking theory with management issues in conservation and management of wildlife populations. During the first half of the course, examples will be drawn worldwide whereas during the second half, the course will focus more strongly on the European fauna, particularly of the Alpine region. Although the course is not designed to teach natural history of the native species, examples will cover much of the taxonomic breadth of the European fauna.

Program (JS: Josef Senn, KB: Kurt Bollmann):

27.9. – Birds and mammals: similarities & differences, evolution, moult in birds (JS & KB)
4.10. – Feeding I: Food, metabolism (KB)
11.10. – Feeding II: Herbivory, Foraging (KB)
18.10. – Distribution and habitat use (KB)
25.10. – Reproduction (KB)
1.11. – Population dynamics (KB)
8.11. – Predation (KB)
15.11. – Competition (JS)
22.11. – Parasitism and diseases (JS)
29.11. – Biogeography of central European birds and mammals (JS)
6.12. – Herbivores as landscape engineers (JS)
13.12. – Exploitation of mammals and birds (JS)
20.12. – Conservation biology, case studies (JS)

Lecture notes
Lecture notes will be available.

Literature
Literature will be listed in the lecture notes. Some additional papers will be distributed.

Some books relevant to the course are (optional reading):
- Suter, W. 2017. Ökologie der Wirbeltiere. Vögel und Säugetiere. UTB/Haupt, Bern. This book is based on the course. It is in German.
Introduction to Environmental Organic Chemistry

The students will understand the impact of environmental factors on plant physiology and will learn the theoretical basis and terminology of plant ecophysiology. They will learn about classical and latest studies in plant ecophysiology that is necessary to analyze yield potentials in agriculture. The students will learn about the functional relevance in the forest ecosystems. To get to know current methodological research approaches, self-reliant and deepened activities of selected topics of fungi from forests.

The focus is on the potential to assess strategies and tactics of pest management, in view of the demands from the economy, environment and society.

The students are able to:
- critically evaluate published work and data.
- identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
- explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination reactions) which determine the environmental behavior of organic pollutants.
- identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
- critically evaluate published work and data.

### Environmental Chemistry/Ecotoxicology

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-0201-00L</td>
<td>Introduction to Environmental Organic Chemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Sander, K. McNeill</td>
</tr>
</tbody>
</table>

This course is an introduction to the environmental chemistry of organic molecules, focusing on equilibrium partitioning processes and non-redox reactions.

- The students are able to:
  - name and recognize the most important classes of environmentally relevant anthropogenic chemicals and identify chemical moieties governing their fate processes.
  - explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination reactions) which determine the environmental behavior of organic pollutants.
  - identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
  - critically evaluate published work and data.
Environmental Physics

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<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>101-0479-00L</td>
<td><strong>Environmental Fluid Dynamics</strong></td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>H. Wernli, M. Röthlisberger</td>
</tr>
</tbody>
</table>

- This course covers the basic physical concepts and mathematical equations used to describe environmental fluid systems on the rotating Earth. Fundamental concepts (e.g. vorticity dynamics and waves) are formally introduced, applied quantitatively and illustrated using examples. Exercises help to deepen knowledge of the material.

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<tr>
<td>101-0203-01L</td>
<td><strong>Hydraulics I</strong></td>
<td>W</td>
<td>5</td>
<td>3V+1U</td>
<td>R. Stocker</td>
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- The course teaches the basics of hydromechanics, relevant for civil and environmental engineers.

### Domain A - Subject-specific Competencies

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Literature</th>
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Further literature will be indicated during the lecture.

### Domain B - Method-specific Competencies

<table>
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<th>Taught competencies</th>
<th>Literature</th>
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### Domain C - Social Competencies

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<th>Taught competencies</th>
<th>Literature</th>
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### Domain D - Personal Competencies

<table>
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<tr>
<th>Taught competencies</th>
<th>Literature</th>
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</table>
Students are able to

The week is mainly about problem solving and design thinking applied to the complex world of health and well-being. During ETH Week students will have the opportunity to work in small interdisciplinary groups, allowing them to critically analyse both their own approaches and those of other disciplines, and to integrate these into their work.

While deepening their knowledge about health and well-being, students will be introduced to various methods and tools for generating creative ideas and understand how different people are affected by each part of the system. In addition to lectures and literature, students will acquire knowledge via excursions into the real world, empirical observations, and conversations with researchers and experts.

A key attribute of the ETH Week is that students are expected to find their own problem, rather than just solve the problem that has been handed to them. Therefore, the first three days of the week will concentrate on identifying a problem the individual teams will work on, while the last two days are focused on generating solutions and communicating the team’s ideas.

No prerequisites. Programme is open to Bachelor and Masters from all ETH Departments. All students must apply through a competitive application process at www.ethz.ch/ethweek. Participation is subject to successful selection through this competitive process.

Take part in the ETH week. No prior knowledge is required

- Domain specific knowledge: Students have immersed knowledge about a certain complex, societal topic which will be selected every year. They understand the complex system context of the current topic, by comprehending its scientific, technical, political, social, ecological and economic perspectives.

- Analytical skills: The ETH Week participants are able to structure complex problems systematically using selected methods. They are able to acquire further knowledge and to critically analyse the knowledge in interdisciplinary groups and with experts and the help of team tutors.

- Design skills: The students are able to use their knowledge and skills to develop concrete approaches for problem solving and decision making to a selected problem statement, critically reflect these approaches, assess their feasibility, to transfer them into a concrete form (physical model, prototypes, strategy paper, etc.) and to present this work in a creative way (role-plays, videos, exhibitions, etc.).

- Self-competence: The students are able to plan their work effectively, efficiently and autonomously. By considering approaches from different disciplines they are able to make a judgment and form a personal opinion. In exchange with non-academic partners from business, politics, administration, nongovernmental organisations and media they are able to communicate appropriately, present their results professionally and creatively and convince a critical audience.

- Social competence: The students are able to work in multidisciplinary teams, i.e. they can reflect critically their own discipline, debate with students from other disciplines and experts in a critical-constructive and respectful way and can relate their own positions to different intellectual approaches. They can assess how far they are able to actively make a contribution to society by using their personal and professional talents and skills and as "Change Agents".

- Remote collaboration competence: The students work in a hybrid setting blending physical and virtual communication and collaboration methods and tools. They experience the potential and limitations of remote collaboration.

The week is mainly about problem solving and design thinking. In 2021, ETH Week will focus on the topic of health and well-being. While deepening their knowledge about health and well-being, students will be introduced to various methods and tools for generating creative ideas and understand how different people are affected by each part of the system. In addition to lectures and literature, students will acquire knowledge via excursions into the real world, empirical observations, and conversations with researchers and experts.

A key attribute of the ETH Week is that students are expected to find their own problem, rather than just solve the problem that has been handed to them. Therefore, the first three days of the week will concentrate on identifying a problem the individual teams will work on, while the last two days are focused on generating solutions and communicating the team’s ideas.

No prerequisites. Programme is open to Bachelor and Masters from all ETH Departments. All students must apply through a competitive application process at www.ethz.ch/ethweek. Participation is subject to successful selection through this competitive process.

<table>
<thead>
<tr>
<th>Taught competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Adaptability and Flexibility</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>Cooperation and Teamwork</td>
<td>Creative Thinking</td>
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<td></td>
<td>Problem-solving</td>
<td>Sensitivity to Diversity</td>
<td>Critical Thinking</td>
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<td></td>
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<td>Negotiation</td>
<td>Self-direction and Self-management</td>
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</tbody>
</table>

701-0951-00L GIS - Introduction into Geoinformation Science and Technology

Theoretical basics and fundamental concepts of Geographic Information Science (GIS) are imparted and subsequently further elaborated with the software ArcGIS.

At the end, the students will be able to independently solve basic realistic GIS problems.

Students are able to

- elucidate the theoretical and conceptional foundations of geographic information systems (GIS)
- independently perform normal GIS work using commercial software and practical examples
### Content

The course covers the following topics:
- What is GIS? What are spatial data?
- The representation of reality by means of spatial data models: vector, raster, TiN
- The four phases of data modelling: Spatial, conceptual, logical and physical model
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Digital elevation models and derived products
- Process modelling with vector and raster data
- Presentation possibilities of spatial data

### Literature

- Bundesamt für Energie: Perspektiven für die Grosswasserkraft in der Schweiz
- UNEP: Global Trends in Renewable Energy Investments
- EIA PVPS: TRENDS 2014 IN PHOTOVOLTAIC APPLICATIONS
- UNEP: Global Trends in Renewable Energy Investments
- Mit einer grünen Anlage schwarze Zahlen schreiben: http://www.rechsteiner-basel.ch/index.php?id=27
- Presentation possibilities of spatial data
- Process modelling with vector and raster data
- Digital elevation models and derived products
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Presentation possibilities of spatial data

### Prerequisites / Literature

One Friday is reserved for a field trip or guest speaker;

PPT presentation will be distributed (in German)


- Bundesamt für Energie: Perspektiven für die Grosswasserkraft in der Schweiz
- UNEP: Global Trends in Renewable Energy Investments
- Mit einer grünen Anlage schwarze Zahlen schreiben: http://www.rechsteiner-basel.ch/index.php?id=27
- Presentation possibilities of spatial data
- Process modelling with vector and raster data
- Digital elevation models and derived products
- Possibilities of data collection
- Transition of reference frame
- Spatial Analysis I: query and manipulation of vector data
- Spatial Analysis II: operators and functions with raster data
- Presentation possibilities of spatial data

### 701-0967-00L Project Development in Renewable Energies

**Objective**

You recognize chances and risks of renewable energy projects

You learn to launch and judge projects by exercises in groups

### Content

- Business models for renewable energy projects
- Introduction of market trends, market structure, technical trends and regulation in Switzerland and in the EU internal energy market
- Necessary frame conditions for profitable projects
- Project development samples and exercises in wind power, solar power and hydro power

### Literature

- REN21 Renewables GLOBAL STATUS REPORT http://www.ren21.net/status-of-renewables/
- Mit einer grünen Anlage schwarze Zahlen schreiben: http://www.rechsteiner-basel.ch/uploads/media/Mit_einer_gruenen_Anlage_schwarze_Zahlen_schreiben.pdf
- Windenergie-Report Deutschland http://windmonitor.iwes.fraunhofer.de/windmonitor_de/5_Veroeffentlichungen/1_windenergiereport/

### Prerequisites / Notice

For group exercise and presentation reasons the number of participants is limited at 30 students. For exercises students build learning and presentational groups.

### 103-0313-00L Spatial Planning and Landscape Development

**Objective**

- The students learn basics of renewable energy project realization from acknowledged experts active in the field.
- They identify different tasks of various investor types.
- They develop sample projects in practice within groups

**Content**

- Realization of projects in the field of renewable energies, analysis of legal frame conditions and risks.
- The students learn basics of renewable energy project realization from acknowledged experts active in the field.
- You become acquainted with the regulatory, juridical and economic requirements of project development in renewable energies in the field of wind power, solar power and hydro power.
- You learn to launch and judge projects by exercises in groups
- You recognize chances and risks of renewable energy projects

### Literature

- REN21 Renewables GLOBAL STATUS REPORT http://www.ren21.net/status-of-renewables/
- Mit einer grünen Anlage schwarze Zahlen schreiben: http://www.rechsteiner-basel.ch/uploads/media/Mit_einer_gruenen_Anlage_schwarze_Zahlen_schreiben.pdf
- Windenergie-Report Deutschland http://windmonitor.iwes.fraunhofer.de/windmonitor_de/5_Veroeffentlichungen/1_windenergiereport/

### Prerequisites / Notice

For group exercise and presentation reasons the number of participants is limited at 30 students. For exercises students build learning and presentational groups.
The course gives a detailed introduction on various aspects of professional project management out of theory and practice. Established Fundamentals of public and collective transport, in its different forms.

Analytical Competencies

Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies. Teaches students to recognize the interactions between the infrastructure design and the production processes, and various performance criteria based on various perspective and stakeholders.

At the end of this course, students can critically analyze existing networks of public transport, their design and use; consider and substantiate different choices of technologies to suitable cases; optimize the use of resources in public transport.

Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings

Vehicles: Classification, design and suitability for different goals

Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

Project Management

Media and Digital Technologies

Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.

Principle of project management - system-technological thinking and acting (challenges, decision levels, decision criteria, solutions, technology activities)

Projects: Projects are not only the base of work in modern enterprises but also the primary type of cooperation with customers. Students of ETH will often work in or manage projects in the course of their career. Good project management knowledge is not only a guarantee for individual, but also for company wide success.

The goal of this course is to give a detailed introduction into project management. The students should learn to plan and execute a project.

Project planning (aims, appointments, capacities, efforts and costs), project organization, scheduling and risk analysis, project execution, supervision and control, project evaluation, termination and documentation, conflict management, multinational project management, IT support as well as agile project management methods such as SCRUM.

The following courses are highly recommended as preparation for the Specialization in Atmosphere and Climate:

- Infrastructure: Planning processes and decision levels in network development and infrastructure planning, planning of topologies; tracks and roadways, station infrastructures; Fundamentals of the infrastructure design for lines; track geometries; switches and crossings
- Vehicles: Classification, design and suitability for different goals
- Network design: design dilemmas, conceptual models for passenger transport on long distance, urban regional transport.
- Operations: Passenger/Supply requirements for line operations; timetabling, measures of realized operations, capacity

No.

The lecture slides and other additional material will be available for download from Moodle a week before each class.

These courses should be successfully completed during the second year.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0459-00L</td>
<td>Seminar for Bachelor Students: Atmosphere and Climate</td>
<td>W</td>
<td>3</td>
<td>2S</td>
<td>R. Knutti, H. Joos, O. Stebler</td>
</tr>
<tr>
<td>701-0461-00L</td>
<td>Numerical Methods in Environmental Sciences</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>C. Schär, C. Zeman</td>
</tr>
<tr>
<td>701-0471-01L</td>
<td>Atmospheric Chemistry</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. Ammann, T. Peter</td>
</tr>
<tr>
<td>701-0473-00L</td>
<td>Weather Systems</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>M. A. Sprenger, F. Scholder-Aemisegger</td>
</tr>
<tr>
<td>701-0475-00L</td>
<td>Atmospheric Physics</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>U. Lohmann</td>
</tr>
</tbody>
</table>

Abstract

In this seminar all students in the realm of atmospheric and climate science from D-ERDW and D-USYS convene to train presentation techniques (talks, posters) by means of classic and modern scientific articles.

Objective

In this seminar, students learn how to read scientific publications and how to transfer the scientific knowledge to a broader audience by means of oral and poster presentations. Students also get insight into the different research areas at the Institute for Atmospheric and Climate Science.

Content

1st week: course organisation and presentation of the institute
2nd and 3rd week: introduction to oral presentation technique
4th week: introduction to poster presentation technique
5th week: poster design
6th week: concluding poster presentation

Lecture notes

Documents are offered via the course's web page.

Prerequisites / notice

This course can only be offered to a limited number of students, however, in any case for everybody having to attend it compulsory. We beg you to sign in to this course early.

30 credits

14th week: concluding poster presentation

11th week: introduction to poster presentation technique

week 4 to 10: students talks

11th week: introduction to poster presentation technique

12th and 13th week: poster design

14th week: concluding poster presentation

Lecture notes

Documents are offered via the course's web page.

Prerequisites / notice

Three obligatory exercises, each two hours in length, are integrated into the lecture. The implementation language is Python (previous experience not necessary: a Python introduction is given). Example programs and graphics tools are supplied.

Lecture notes


Literature

List of literature is provided.

701-0471-01L

Objective

The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will understand the most important chemical processes in the troposphere and the stratosphere.

Content

- Chemistry of aerosols and clouds: particle transfer, N2O5 chemistry, SO2 oxidation, secondary organic aerosol formation
- Thermodynamics and kinetics of gas phase reactions: enthalpy and free energy of reactions, rate laws, mechanisms of bimolecular and termolecular reactions.
- Tropospheric photochemistry: Photolysis reactions, photochemical O3 formation, role and budget of HOx, dry and wet deposition
- Aerosol and clouds: chemical properties, primary and secondary aerosol sources, solubility of gases, hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, SO2 oxidation, secondary organic aerosol formation
- Air quality: role of planetary boundary layer, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Stratocumulus chemistry: Chapman cycle, Brewer-Dobson circulation, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Global aspects: global budgets of ozone, methane, CO and NOx, air quality - climate interactions

Lecture notes

Lecture materials (slides) are provided continuously during the semester, at least 2 days before each lecture.

Prerequisites / notice

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.

On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.

701-0473-00L

Abstract

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Objective

The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Content

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Lecture notes

Lecture notes and slides

Literature

Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

701-0475-00L

Abstract

In this course, students will learn the fundamentals of gas phase reactions, the concept of solubility and reactions in aerosols and in clouds. It explains the chemical and physical processes responsible for global (e.g. stratospheric ozone depletion) as well as regional (e.g. urban air pollution) environmental problems.

Objective

The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will understand the most important chemical processes in the troposphere and the stratosphere.

Content

- Origin and properties of the atmosphere: composition (gases and aerosols), structure, large scale dynamics, UV radiation
- Thermodynamics and kinetics of gas phase reactions: enthalpy and free energy of reactions, rate laws, mechanisms of bimolecular and termolecular reactions.
- Tropospheric photochemistry: Photolysis reactions, photochemical O3 formation, role and budget of HOx, dry and wet deposition
- Aerosol and clouds: chemical properties, primary and secondary aerosol sources, solubility of gases, hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, SO2 oxidation, secondary organic aerosol formation
- Air quality: role of planetary boundary layer, summer- versus winter-smog, environmental problems, legislation, long-term trends
- Stratocumulus chemistry: Chapman cycle, Brewer-Dobson circulation, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol
- Global aspects: global budgets of ozone, methane, CO and NOx, air quality - climate interactions

Prerequisites / notice

Number

These courses should be successfully completed during the second year.
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

Students are able - to explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics. - to evaluate the significance of clouds and aerosol particles for artificial weather modification.

The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clayperon equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to classify radiosondes with the help the thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artificial weather modification ideas.

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15387


If the students are able to explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination governing their fate processes.

- critically evaluate published work and data.

- Overview of the most important classes of environmentally relevant anthropogenic chemicals and identify chemical moieties etc) and partitioning behavior of organic compounds between environmentally relevant phases (air, aerosols, soil, water, biota)

- Physical-chemical properties (vapor pressure, aqueous solubility, air-water partition constant, organic solvent-water partition constants, etc) and partitioning behavior of organic compounds between environmentally relevant phases (air, aerosols, soil, water, biota)

- Chemical transformation reactions of organic pollutants in aquatic and in terrestrial environments (hydrolysis, elimination, addition)

- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

*****Biogeochemistry

The following courses are highly recommended as preparation for the Specialization in Biogeochemistry:

701-0225-00L Organic Chemistry (Autumn semester)
752-0100-00L Biochime (Autumn semester)
752-1300-00L Introduction to Toxicology (Spring semester)

These courses should be successfully completed during the second year.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0201-00L</td>
<td>Introduction to Environmental Organic Chemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Sander, K. McNeill</td>
</tr>
</tbody>
</table>

Abstract

This course is an introduction to the environmental chemistry of organic molecules, focusing on equilibrium partitioning processes and non-redox reactions.

Objective

The students are able to

- name and recognize the most important classes of environmentally relevant anthropogenic chemicals and identify chemical moieties governing their fate processes.
- explain, on the basis of physical-chemical foundations, the most important processes (i.e., partitioning and substitution and elimination reactions) which determine the environmental behavior of organic pollutants.
- identify, on the basis of chemical structure, the processes relevant for the environmental behavior of a compound.
- critically evaluate published work and data.

Content

- Overview of the most important classes of environmental organic pollutants
- Molecular interactions that determine the partitioning behavior (adsorption and absorption processes) of organic compounds between different environmental compartments (gas, liquid, solid)
- Physical-chemical properties (vapor pressure, aqueous solubility, air-water partition constant, organic solvent-water partition constants, etc) and partitioning behavior of organic compounds between environmentally relevant phases (air, aerosols, soil, water, biota)
- Chemical transformation reactions of organic pollutants in aquatic and in terrestrial environments (hydrolysis, elimination, addition)

Lecture notes

Script will be distributed

Literature


Prerequisites / notice

Die Lehrveranstaltung richtet sich nicht nur an jene Studierenden, welche sich später chemisch vertiefen wollen, sondern ausdrücklich auch an alle jene, welche sich mit der Problematik von organischen Schadstoffen in der Umwelt vertraut machen wollen, um dieses Wissen in anderen Vertiefungen anzuwenden

701-0419-01L Seminar for Bachelor Students: Biogeochemistry | W | 3 credits | 2S | D. I. Christl, A. N'Guyen van Chinh

Abstract

Current research topics are presented and discussed based on scientific literature. The students prepare a presentation with the support of an expert. Subsequently, the topics are discussed jointly by students and experts in student-moderated discussion rounds. Presentation and moderation techniques are introduced and trained in the seminar, supported by instructions for constructive feedback.
Objective: The seminar aims at introducing the students to current research in the field of biogeochemistry and connect them with researchers. After the seminar, students are able to …
- understand and critically evaluate original scientific papers and to communicate their findings in a coherent way (presentation); in doing so, they become familiar with different types of publications and relevant journals in the field of biogeochemistry;
- discuss scientific results, plan and lead discussion rounds (moderation);
- give and receive constructive feedback.

Content: Part 1: Literature search; presentation and moderation techniques.
Part 2: Literature study; online-exchange of information; presentation and discussion moderated by students.

Lecture notes: Selected handouts will be distributed in class.
https://moodle-app2.let.ethz.ch/auth/shibboleth/login.php

Prerequisites / notice: Deadline for enrollment is the FIRST day of the semester. Later enrollment can only be accepted in exceptional cases and under certain conditions (e.g., restricted choice of topics and dates).

701-0533-00L  Soil and Water Chemistry  W  3 credits  2G  R. Kretzschmar, D. I. Christl, L. Winkel

Abstract: This course covers chemical and biogeochemical processes in soils and water and their influence on the behavior and cycling of nutrients and pollutants in terrestrial and aquatic systems. Approaches for quantitative modeling of the processes are introduced and applied in selected examples.

Objective 1. Understanding of important chemical properties and processes of soils and water and their influence on the behavior (e.g., chemical speciation, bioavailability, mobility) of nutrients and pollutants.
2. Quantitative applications of chemical equilibria to processes in natural systems.

Content: Chemical equilibria in aqueous solutions, gas equilibria, precipitation and dissolution of mineral phases, silicate weathering, weathering kinetics, formation of secondary minerals (clay minerals, oxides, sulfides), redox processes in natural systems, pH buffering and acidification, salinity and salinization, environmental behavior of selected essential and toxic trace elements.

Literature:–Chapters 1, 3, 4, 6, 7 and 11 in Sigg/Stumm – Aquatische Chemie, 6. Auflage, vdf, 2016.

Prerequisites / notice: The lecture courses Pedosphere and Hydrosphere are highly recommended.

701-0535-00L  Environmental Soil Physics/Vadose Zone Hydrology  W  3 credits  2V+1U  A. Carminati, P. U. Lehmann Grunder

Abstract: The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

Objective: Students are able to
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

Content: Week 1: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;
Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab
Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components
Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab
Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)
Week 7: Unsaturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow
Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project
Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow
Week 10: Root water uptake and transpiration
Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.
Week 12: Summary of lectures; solution of old exam
Week 13: Written semester-end exam
Week 14: Short presentations of Hydrus class projects; discussion of written exam

Literature: Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Research in human-environment systems is characterised by a broad range of topics and methods. This is illustrated by the research papers that are discussed in this seminar. Students choose a paper from a list and present it to the seminar participants. Furthermore, they lead the discussion and train questions and answers related to such presentations. In the first three lessons, inputs to presentation techniques and innovative approaches to presentations are provided and discussed.

The course will focus on integrated landscape approaches for the management of tropical forest landscapes, by addressing the complex interactions between ecological processes, stakeholders' strategies and public policies. Dedicated tools such as games and simulation models to improve knowledge and foster collective decision-making processes will be explored.

A major objective of the course is to encourage students to develop a critical analysis of existing conservation and development narratives within the frame of agroforestry and forested agricultural landscapes. The course will also provide students with methods and tools to assess stakeholders perceptions/practices and knowledge, that will be of use in their professional life.

The course will address:

- Definitions of forests and agroforests, deconstructing the rigid historical divisions between these two, and showing the complexities and implications legal definitions will have on the management systems. We will also address the definitions of Social and Ecological System (SES) and Resilience, useful for the entire course. We will provide insights on how to describe the SES using the ARDI methodology (Actors, Resources, Dynamics and Interactions)
- Methodological frameworks to understand drivers and coping strategies of stakeholders (Sustainable livelihood framework & Vulnerability; Ecosystem Services & trade-offs; Companion Modelling and Adaptive Management; Surveys and Participatory Appraisals)

The course will tackle new and emerging topics such as the role of forests and trees in adaptation to climate change, the links between forest, poverty and food security, and the need to mainstream conservation of biodiversity outside protected areas. The course will draw from diverse disciplines, from ecology, economy, sociology, political sciences and legal studies as the most preeminent ones.

The course will engage the scope of the students from the ecological process to the social and political components of tropical social and ecological systems. It will address topics and case studies that the students will have little opportunity to address elsewhere, linking them to issues of global relevance in environmental sciences.

A. Müller

Lecture notes
Will be provided in the seminar.

Literature

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
<th>Journal/Source</th>
<th>Year</th>
</tr>
</thead>
</table>
Environmental decision-making is at the core of sustainability policies and management of human-environment systems. This lecture provides an introduction to the conceptual background for environmental decision-making and teaches the practicalities of environmental decision-making by means of exemplary real world cases.

The course starts with the introduction of basic topics related to environmental decision-making. It then switches to a flipped-classroom format with individual project work. In this project work, the students work with existing governmental, academic, NGO, etc. reports on specific situations that involve environmental decision-making. The course closes with a synthesis of the project work in the plenary. The second half of the semester focuses on a short individual project on a case of environmental decision-making chosen by each student, again organised in flipped-classroom format. The lecture closes with plenary lessons where the group work and individual project work is located in a broader context of central aspects of environmental decision-making and where a synthesis is drawn on the topics addressed in this lecture.

This course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, including the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

The course covers the all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power. When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

This course covers basic questions, concepts, theories, methods, and empirical findings of political science. This course covers basic questions, concepts, theories, methods, and empirical findings of political science. This course covers basic questions, concepts, theories, methods, and empirical findings of political science.


Tipp: Lesen Sie zuerst genau die Übungsaufgaben für das zu bearbeitende Buchkapitel (https://ib.ethz.ch/teaching/pvgrundlagen.html) und erst danach das betreffende Kapitel. Sie wissen dann beim Lesen schon vorweg, auf was Sie besonders genau schauen sollten.


Übungsaufgaben und ein Glossar finden Sie hier: https://ib.ethz.ch/teaching/pvgrundlagen.html

Leistungskontrollen

a) Erster Test (12.11.2021, 14:15–15:00)

b) Zweiter Test (17.12.2021, 14:15–15:00)

Jede Fahrt in der COVID-19 Situation werden die beiden Tests entweder im Kursraum oder online durchgeführt (ausschliesslich eine der beiden Varianten, keine Wahlmöglichkeit).

Kreditpunkte

4 ECTS-Punkte (Zeitaufwand insgesamt ca. 120 Arbeitsstunden)
This course provides the ecological systems’ knowledge needed to question applied solutions to current environmental issues. Our central

Objective
At the end of the course...
...you know how to structure your inquiry and how to proceed the analysis when faced with a complex environmental issue. You can formulate the relevant questions, find answers (supported by discussions, input from the lecturers and the literature), and you are able to present your conclusions clearly and cautiously.

...you understand that biodiversity and the interaction between organisms are an integral part of ecosystems. You are aware that the link between biodiversity and process/function/service is rarely fully understood. You know how to honestly deal with this lack of understanding and can nevertheless find, critically analyse and communicate solutions.

...you understand the importance of ecosystem services for society.

...you have an overview of the methods of ecosystem research and have a deeper insight into some of them, e.g. ecosystem observation, manipulation and modelling.

...you have reflected on ecology as a young discipline at the heart of significant applied questions.

Lecturer
A. Gessler, C. Grossiord

Environmental Biology
The following courses are highly recommended as preparation for the Specialization in Environmental Biology:

227-0399-10L Physiology and Anatomy for Biomedical Engineers I (Autumn semester)
551-0435-00L Systematische Biologie: Zoologie (Spring semester)
701-0360-10L Systematische Biologie: Pflanzen (Spring semester)
227-0398-10L Physiology and Anatomy for Biomedical Engineers II (Spring semester)

These courses should be successfully completed during the second year.


Sie müssen die zugewiesenen Buchkapitel vor der jeweiligen Kursseinheit gründlich lesen und Fragen notieren, damit wir effizient vorankommen. Pro Kursseinheit (Woche) sind ca. 30–40 Seiten zu lesen. Für einzelne Kursseiten müssen Sie etwas mehr lesen (zwei Buchkapitel, ca. 60–80 Seiten insgesamt). Es lohnt sich also, bereits von Anfang des Kurses an ein wenig «auf Vorrat» zu lesen.

Tutorat: Im Tutorat wird das aus der Lektüre der Buchkapitel sowie der Vorlesung mitgebrachte Wissen weiter vertieft, u.a. anhand von möglichen Testfragen. Eine regelmäßige und engagierte Teilnahme am Tutorat, die gründliche Lektüre der Buchkapitel und die Teilnahme an der Vorlesung stellen sicher, dass Sie bei den Tests keine «Überraschungen» erleben werden.


Bei einer Gesamtnote (auf 0.25 gerundeter Mittelwert der beiden Tests) ≥ 4.0 gilt der Kurs als bestanden und es werden vier ECTS Punkte zugeteilt. Ausnahme: Im BA Staatswissenschaften werden die vier ECTS Punkte erst nach erfolgreichem Absolvieren der Basisprüfung zugeteilt.

Für die Studierenden des BA Staatswissenschaften ist der Inhalt dieses Kurses Prüfungstoff für die Hälfte der Basisprüfung im Fach Politikwissenschaft, die von Prof. Bernauer durchgeführt wird (die zweite Hälfte der Basisprüfung führt Prof. Schimmelfennig durch). Das Absolvieren der beiden Tests während des Semesters ist für Studierende des BA Staatswissenschaften freiwillig, aber stark empfohlen. Für jeden der beiden Tests erhalten Sie bei einer Note von 4 oder mehr einen Bonus für die Basisprüfung im Fach Politikwissenschaft. Sie können also durch das Absolvieren der beiden Tests in der Basisprüfung verbessern bzw. ein Polster erwerben.

Prüfungstoff ist der gesamte Inhalt der Vorlesung und des Tutorats. Für diesen Kurs ist keine zusätzliche (separate) Prüfungsanmeldung nötig, die Anmeldung für den Kurs im mystudies deckt alles ab.

Für die beiden Tests dürfen Sie vier Seiten Notizen benutzen (zwei Blätter beidseitig beschrieben). Bitte beachten Sie, dass die Notizblätter handschriftlich beschrieben sein müssen. Elektronisch bedruckte Notizblätter werden ausnahmslos nicht zur Prüfung zugelassen.

Wenn Sie gerne mehr über sozialwissenschaftliche Konzepte und Forschungsmethoden lernen möchten, sind diese beiden Bücher ausserordentlich gut:
Week 1: Choice of topics and tutors
Students are familiar with fundamental concepts in ecological genetics and with current scientific methods. They can propose strategies to
A. Carminati

It is not essential to borrow/buy the following books. We will continuously provide excerpts and other literature during the course.

Prerequisites / notice
The course combines elements of a classic lecture, group discussions and problem based learning. It is helpful, but not essential to be familiar with the "seven stages" method (see e.g. course 701-0352-00L "Analysis and Assessment of Environmental Sustainability" by Christian Pohl et al.).

701-0320-00L Seminar for Bachelor Students: Environmental Biology W 3 credits 2S D. Ramseier

Abstract
In the seminar, students explore a specific topic in environmental biology (ecology, evolution, health). They find and read scientific articles, structure contents around core questions, talk to specialists about them, prepare a scientific presentation and lead a discussion. They are introduced to literature search and scientific presentations.

Objective
Students will acquire skills in:
- finding literature in scientific databases
- structuring a scientific topic through research questions
- giving a clear scientific presentation
- contributing constructively to a scientific discussion

Content
Week 1: Choice of topics and tutors
Week 2: Literature search
Week 4: course for presentation techniques
Weeks 1 - 5: Meetings with tutors, preparation of presentations
Weeks 5 - 14: Presentations and discussions

Lecture notes
Will be handed out during classes

701-1413-00L Population and Quantitative Genetics W 3 credits 2V T. Städler, J. Stapley

Abstract
This course is an introduction to the rapidly developing fields of population and quantitative genetics, emphasizing the major concepts and ideas over mathematical formalism. An overview is given of how mutation, genetic drift, gene flow, mating systems, and selection affect the genetic structure of populations. Evolutionary processes affecting quantitative and Mendelian characters are discussed.

Objective
Students are able to
- describe types and sources of genetic variation.
- describe fundamental concepts and methods of quantitative genetics.
- use basic mathematical formalism to describe major population genetic concepts.
- discuss the main topics and developments in population and quantitative genetics.
- model population genetic processes using specific computer programs.

Content
Population Genetics:
- Types and sources of genetic variation; randomly mating populations and the Hardy-Weinberg equilibrium; effects of inbreeding; natural selection; random genetic drift and effective population size; gene flow and hierarchical population structure; molecular population genetics: neutral theory of molecular evolution and basics of coalescent theory.

Quantitative Genetics:
- Continuous variation; measurement of quant. characters; genes, environments and their interactions; measuring their influence; response to selection; inbreeding and crossbreeding, effects on fitness; Fisher's fundamental theorem.

Lecture notes
Handouts

701-1413-01L Ecological Genetics W 3 credits 2V A. Widmer, S. Fior, M. C. Fischer

Abstract
This course focuses on fundamental concepts and methods in ecological genetics. Topics covered include genetic diversity, natural selection, adaptation, reproductive isolation, hybridization and speciation.

Objective
Students are familiar with fundamental concepts in ecological genetics and with current scientific methods. They can propose strategies to study evolutionary processes in natural populations by combining their knowledge from different disciplines, including population and quantitative genetics, ecology and evolution.

Content
Concepts and methods for the study of genetic diversity, biodiversity, natural selection, adaptation, reproductive isolation, hybridization and speciation.

Lecture notes
Handouts will be provided electronically.

Prerequisites / notice
We recommend that you also follow the course 701-1413-00L - Population and Quantitative Genetics either in advance or in parallel.

Forest and Landscape
The following courses are highly recommended as preparation for the Specialization in Forest and Landscape:

701-0266-00L Einführung in die Dendrologie (Autumn semester)
551-0435-00L Systematische Biologie: Zoologie (Spring semester)
701-0360-00L Systematische Biologie: Pflanzen (Spring semester)

These courses should be successfully completed during the second year.

Number Title Type ECTS Hours Lecturers
701-0535-00L Environmental Soil Physics/Vadose Zone Hydrology W 3 credits 2V+1U A. Carminati, P. U. Lehmann Grunder
The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils/near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

Students are able to
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

Week 1: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume-relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;

Week 2: Pore scale consideration, pore sizes, shapes and connectivity, coordination number, continuity and percolation, surface area, soil structure

Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab

Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components

Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab

Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille’s Law); Darcy’s Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)

Week 7: Unsaturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow

Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of saturated flow; choosing class project

Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow

Week 10: Root water uptake and transpiration

Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.

Week 12: Summary of lectures; solution of old exam

Week 13: Written semester-end exam

Week 14: Short presentations of Hydrus class projects; discussion of written exam

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel

Lecture notes

701-0553-00L Landscape Ecology W 3 credits 2G F. Kienast, L. Pellissier

Abstract

The course is an introduction to Landscape Ecology and Landscape Modelling and provides various practical applications of Landscape Ecology in nature and landscape management.

Objective

The students are able to
- to explain and apply the concepts and methods of landscape analysis using examples,
  - to explain causes and effects of changes in landscape using examples and simulations,
  - to describe practical applications of Landscape Ecology in the management of nature and landscape.

Content

Contents of the lecture:
- important terms and concepts of Landscape Ecology,
- analysis of landscape pattern (metrics),
- landscape modelling,
- perception of landscapes,
- landscape inventories used for nature and landscape protection.

Lecture notes

The course is offered via a MOOC (Edx) in the MOOC

Literature

It is advantageous but not required to have some GIS knowledge for this lecture and the practical ‘Praktikum Wald und Landschaft’ (spring semester) which is loosely linked with this lecture.

701-0559-00L Seminar for Bachelor Students: Forest and Landscape W 3 credits 2S M. Lévesque, T. Ohmura

Abstract

Interdisciplinary seminar on forest and landscape issues with particular emphasis on the key processes shaping the development of forest ecosystems and landscapes.

Objective

- To critically analyze and discuss original scientific articles for selected processes and methods in relation to forest and landscape.
- Scientific exchange with subject-specific experts.
- Learn standard rhetoric and moderation methods through training in the seminar.
- Effective feedback regarding the independent development of presentation and moderation competencies.

Content

Seminars will deal with the following topics: 1) Biological, ecological and physical processes, and technical aspects in forest ecosystems with effects on the community, ecosystem and landscape; 2) Social and political processes and institutions with relation to land use; 3) Products and services of forest ecosystems and landscapes and 4) Forest management systems. The contributions will be grouped by topics. Furthermore, the seminar teaches rhetoric and moderation methods, which will serve to deepen the above topics through presentations and discussions.

Lecture notes

There will be a script for the rhetoric and moderation methods.

Literature references will be provided by the lecturers.

Prerequisites / notice

The credits are assigned if the following requirements are met

a) Independent literature research on the topic and exchange with experts for preparing for the presentation
b) Presentation with questions and answers (15-20 min)
c) Moderation of the scientific discussion (20-35 min)
d) Actively contributing to the feedback of students' presentations, moderation and discussions.

The presentations can be made in German or English.

We expect a regular and active participation.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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</thead>
<tbody>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Techniques and Technologies</td>
<td>assessed</td>
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<tr>
<td>Domain C - Social Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
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<td></td>
<td>Media and Digital Technologies</td>
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<td>Communication</td>
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<td></td>
<td>Cooperation and Teamwork</td>
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<td></td>
<td>Self-presentation and Social Influence</td>
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<td></td>
<td>Sensitivity to Diversity</td>
<td>assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>Creative Thinking</td>
<td>assessed</td>
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<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
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<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>assessed</td>
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### 701-0561-00L  
**Forest Ecology**  
**W 3 credits 2V** C. Bigler  

#### Abstract  
This course conveys the basics of forest ecology with an emphasis on trees as those organisms that dominate the physiognomy and the dynamics of forest ecosystems. Based on this course, students have a good grasp of the qualitative and quantitative importance of forest ecosystems at the global and regional scales, with a focus on central Europe.

#### Objective  
Students are able to:

1. Summarize the fundamentals of forest ecology at the autecological, demecological and synecological level.
2. Explain how trees dominate the physiognomy and dynamics of forest ecosystems.
3. Describe the qualitative and quantitative importance of forest ecosystems at the global and regional scales, with an emphasis on central Europe and Alpine regions.

#### Content  
- Introduction and overview of the forests of the world
- Forest ecosystem ecology: Production ecology of forests
- Autecology: light, temperature, wind, water, and nutrients
- Demecology: regeneration ecology, forest growth, mortality
- Synecology: fundamentals of trophic interactions (forest-ungulate interactions), succession

#### Lecture notes  
Handouts (mixture of overhead slides and full text chapters) are sold at cost. Relevant chapters from textbooks will be indicated.

#### Literature  

### 701-0565-00L  
**Fundamentals of Natural Hazards Management**  
*Does not take place this semester.*  
**W 3 credits 3G** V. Griess, B. Krummenacher, S. Löw

#### Abstract  
Risks to life and human assets result when settlement areas and infrastructure overlap regions where natural hazard processes occur. This course utilizes case studies to teach how a future natural hazards-specialist should analyze, assess and manage risks. The objectives of this course are explained step-by-step through a set of case studies, and applied in lab by the students. The following principal steps are used when coping with natural hazard-risks. At each step, students will learn and apply the following skills:

- **Risk analysis - What can happen?**
  - Characterize the processes and environmental measures that lead to a natural hazard and integrate modeling results of these processes.
- **Risk assessment - What are the acceptable levels of risk?**
  - Apply principles to determine acceptable risks to human life and assets in order to identify locations which should receive added protection.
  - Explain conflicts for risk perception and risk analysis.
- **Risk management - What steps should be taken to manage risks?**
  - Explain how various hazard mitigation approaches reduce risk.
  - Describe hazard scenarios as a base for adequate dimensioning of control measures.
  - Identify the best alternative from a set of thinkable measures based on an evaluation scheme.
  - Explain the principles of risk-governance.

#### Content  
Die Vorlesung besteht aus folgenden Blöcken:

1. Einführung ins Vorgehenskonzept (1W)
2. Risikokonzept (6W + Exkursion) mit:
   - Systemabbildung
   - Gefahrenbeurteilung
   - Expositions- und Folgenanalyse
3. Risikobewertung (2W)
4. Risikomanagement (2W + Exkursion)
5. Abschlussbesprechung (1W)

### 701-0567-00L  
**Forest Health: Entomology and Pathology**  
**W 3 credits 2V+1P** E. Brockerhoff, V. Queloz

#### Abstract  
Insects and microorganisms are important components of the biodiversity and ecology of forests. This course covers the diversity, biology and ecology of insects and pathogens, both native and non-native species and especially those that are tree pests or cause diseases. The course also covers entomological and pathological methods, forest protection and other relevant topics.

#### Objective  
Basic knowledge of:

- Biology, ecology and biodiversity of insects and the main insect orders with examples of beneficial and pest species of trees and forests of central Europe.
- the various groups of tree pathogens (fungi, oomycetes, bacteria, viruses) as well as abiotic causes of tree diseases.
- the most important concepts such as forest health, disposition, resistance, interactions, vectors, epidemiology, outbreaks, invasive species and climatic factors.
- methods for monitoring and sustainable prevention and limitation of damage from insects and pathogens.
Bachelor's Thesis

**In principle, all professors and lecturers involved in the teaching of the Environmental Sciences degree programme are entitled to supervise a Bachelor's thesis (BA).** BA in the area of social sciences and humanities can only be supervised by lecturers who teach in this area. The same applies to BA in the field of natural sciences and technology.

If the thesis is supervised by a person who does not teach in the Environmental Sciences degree programme or who does not have ETH lecturer status, then the student has to fill in the form "Supervisors not selectable via myStudies" https://ethz.ch/content/dam/ethz/special-interest/usys/department/documents/studium/umweltnaturwissenschaften/bachelor/bsc-envsci-supervisors-not-listed-mystudies.pdf

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### 701-0010-02L Short Bachelor's Thesis in Social Sciences and Humanities

**Abstract**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature. Depending on the chosen orientation of the thesis, the students learn these skills through an empirical analysis, a literature review, via design tasks or through an applied project.

**Objective**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature.

**Content**
A bachelor's thesis in the domain "Social sciences and humanities" usually deals with an issue at the interface of those sciences, the environment and sustainability. Methods of data collection, analysis and interpretation stemming from the social sciences are applied. A short bachelor's thesis should consist of a text, with graphs and figures, of 15-20 pages.

---

### 701-0010-03L Short Bachelor's Thesis in Natural Sciences and Engineering

**Abstract**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature. Depending on the chosen orientation of the thesis, the students learn these skills through an empirical analysis, a literature review, via design tasks or through an applied project.

**Objective**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature.

**Content**
A bachelor's thesis in "Natural sciences" deals with a topic at the interface of natural sciences, the environment and sustainability. The methods of data collection, analysis and interpretation appropriate to the natural sciences are used. A thesis in "Engineering" deals with the environmental effects of use and application. The thesis may take the form of an analysis or review of a current technology, or the design of a future technological application. An inter- or transdisciplinary thesis, knowledge from various fields and disciplines would be merged on the basis of an overarching question, or developed via the input of key societal actors. A short bachelor's thesis should consist of a text, with graphs and figures, of 15-20 pages.

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### 701-0010-10L Bachelor's Thesis

**Abstract**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature. Depending on the chosen orientation of the thesis, the students learn these skills through an empirical analysis, a literature review, via design tasks or through an applied project.

**Objective**
By developing the bachelor's thesis, students learn to (a) analyse a problem using scientific methods and concepts, (b) write a report according to scientific standards and (c) correctly cite scientific literature.

**Content**
The BA is written either under the "Social sciences and humanities" or the "Natural sciences and technology" modules. The thesis may also be inter- and transdisciplinary. A bachelor's thesis in the domain "Social sciences and humanities" usually deals with an issue at the interface of those sciences, the environment and sustainability. Methods of data collection, analysis and interpretation appropriate to the natural sciences are used. A thesis in "Technology" deals with the environmental effects of use and application. The thesis may take the form of an analysis or review of a current technology, or the design of a future technological application. An inter- or transdisciplinary thesis, knowledge from various fields and disciplines would be merged on the basis of an overarching question, or developed via the input of key societal actors. A bachelor's thesis should consist of a text, with graphs and figures, of 30-40 pages.

## Environmental Sciences Bachelor - Key for Type

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>O</td>
<td>Compulsory</td>
<td>E- Recommended, not eligible for credits</td>
</tr>
<tr>
<td>W+</td>
<td>Eligible for credits and recommended</td>
<td>Z Courses outside the curriculum</td>
</tr>
<tr>
<td>W</td>
<td>Eligible for credits</td>
<td>Dr Suitable for doctorate</td>
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**Data:** 14.12.2021 12:41  **Autumn Semester 2021**  **Page 2066 of 2152**
### Key for Hours

<table>
<thead>
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<th>Key</th>
<th>Description</th>
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<tr>
<td>V</td>
<td>lecture</td>
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<td>G</td>
<td>lecture with exercise</td>
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<td>U</td>
<td>exercise</td>
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<td>S</td>
<td>seminar</td>
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<td>K</td>
<td>colloquium</td>
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<td>P</td>
<td>practical/laboratory course</td>
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<td>A</td>
<td>independent project</td>
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<td>D</td>
<td>diploma thesis</td>
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<tr>
<td>R</td>
<td>revision course / private study</td>
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### ECTS

- European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.
Environmental Sciences Master

Major in Atmosphere and Climate

Prerequisites

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-0471-01L</td>
<td>Atmospheric Chemistry</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>M. Ammann, T. Peter</td>
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<td></td>
<td>Abstract</td>
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<td>The lecture provides an introduction to atmospheric chemistry at bachelor level. It introduces the fundamentals of gas phase reactions, the concept of solubility and reactions in aerosols and in clouds. It explains the chemical and physical processes responsible for global (e.g. stratospheric ozone depletion) as well as regional (e.g. urban air pollution) environmental problems.</td>
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<td>Objective</td>
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<td></td>
<td>The students will understand the basics of gas phase reactions and of reactions and processes in aerosols and clouds. The students will understand the most important chemical processes in the troposphere and the stratosphere. The students will also acquire a good understanding of atmospheric environmental problems including air pollution, tropospheric ozone formation, stratospheric ozone destruction and the relationship between air pollution and climate change.</td>
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<td>Content</td>
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<tr>
<td></td>
<td>- Origin and properties of the atmosphere: composition (gases and aerosols), structure, large scale dynamics, UV radiation</td>
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<td></td>
<td>- Thermodynamics and kinetics of gas phase reactions: enthalpy and free energy of reactions, rate laws, mechanisms of bimolecular and termolecular reactions.</td>
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<td></td>
<td>- Tropospheric photochemistry: Photolysis reactions, photochemical O3 formation, role and budget of HOx, dry and wet deposition</td>
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<tr>
<td></td>
<td>- Aerosols and clouds: chemical properties, primary and secondary aerosol sources, solubility of gases, hygroscopicity, kinetics of gas to particle transfer, N2O5 chemistry, SO2 oxidation, secondary organic aerosol formation</td>
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<td></td>
<td>- Air quality: role of planetary boundary layer; summer- versus winter-snow; environmental problems, legislation, long-term trends</td>
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<td></td>
<td>- Stratospheric chemistry: Chapman cycle, Brewer-Dobson circulation, catalytic ozone destruction cycles, polar ozone hole, Montreal protocol</td>
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<tr>
<td></td>
<td>- Global aspects: global budgets of ozone, methane, CO and NOx, air quality - climate interactions</td>
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</tbody>
</table>

Lecture notes

Lecture notes (slides) are provided continuously during the semester, at least 2 days before each lecture.

Prerequisites / notice

Attendance of the lecture "Atmosphäre" LV 701-0023-00L or equivalent knowledge is a pre-requisite, and basic courses in physics and chemistry are expected.

On Mondays (or upon agreement) a tutorial is offered. This allows the students to discuss unresolved issues from the lecture or to discuss the problems of the exercise series and their solution. Participation is recommended.

701-0473-00L Weather Systems

Abstract

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Objective

The students are able to
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Content

Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Lecture notes

Lecture notes and slides

Literature

Atmospheric Science, An Introductory Survey
John M. Wallace and Peter V. Hobbs, Academic Press

701-0475-00L Atmospheric Physics

Abstract

This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation especially prediction of thunderstorm development, aerosol physics as well as artificial weather modification.

Webpage for course: https://iac.ethz.ch/edu/courses/bachelor/verteilung/atmospheric-physics.html

Objective

Students are able
- to explain the mechanisms of thunderstorm formation using knowledge of thermodynamics and cloud microphysics.
- to evaluate the significance of clouds and aerosol particles for artificial weather modification.

Content

The course starts with introducing selected concepts of thermodynamics for atmospheric processes: The students learn the concept of the thermodynamic equilibrium and derive the Clausius-Clapeyron equation from the first law of thermodynamics. This equation is central for the phase transitions in clouds.

Students also learn to classify radiosondes with the help the thermodynamic charts (tephigrams) and to identify cloud base, cloud top, available convective energy in them. Atmospheric mixing processes are introduced for fog formation. The concept of the air parcel is used to understand convection.

Aerosol particles are introduced in terms of their physical properties and their role in cloud formation based on Köhler theory. Thereafter cloud microphysical processes including ice nucleation are discussed.

With these basics, the different forms of precipitation formation (convective vs. stratiform) is discussed as well as the formation and different stages of severe convective storms.

The concepts are applied to understand and judge the validity of different proposed artifical weather modification ideas.

Lecture notes

Powerpoint slides and chapters from the textbook will be made available on moodle: https://moodle-app2.let.ethz.ch/course/view.php?id=15367

Literature

Lohmann, U., Lübßörd, F. and Mahrt, F., An Introduction to Clouds:
From the Microscale to Climate. Cambridge Univ. Press, 391 pp., 2016.

Prerequisites / notice

50% of the time we use the concept of "flipped classroom" (en.wikipedia.org/wiki/Flipped_classroom), which we introduce at the beginning.

We offer a lab tour, in which we demonstrate how some of the processes discussed in the lectures are measured with instruments.

There is an additional tutorial right after each lecture to give you the chance to ask further questions and discuss the exercises. The participation is recommended but voluntary.
### Mandatory Courses

#### Introduction Course

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1213-00L</td>
<td>Introduction Course to Master Studies Atmosphere and Climate</td>
<td>O</td>
<td>2 credits</td>
<td>2G</td>
<td>H. Joos, T. Peter</td>
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</table>

#### Colloquia

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>651-4095-01L</td>
<td>Colloquium Atmosphere and Climate 1</td>
<td>O</td>
<td>1 credit</td>
<td>1K</td>
<td>H. Joos, H. Wernli, D. N. Bresch, D. Domeisen, N. Gruber, R. Knutti, U. Lohmann, T. Peter, C. Schär, S. Schemm, S. I. Seneviratne, M. Wild</td>
</tr>
</tbody>
</table>

#### Seminars

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1211-01L</td>
<td>Master’s Seminar: Atmosphere and Climate 1</td>
<td></td>
<td>O</td>
<td>3 credits</td>
<td>2S</td>
</tr>
</tbody>
</table>
In this seminar, the process of writing a scientific proposal will be introduced. The essential elements of a proposal, including the peer review process, will be outlined and class exercises will train scientific writing skills. Knowledge exchange between class participants is promoted through the preparation of a master thesis proposal and evaluation of each other’s work.

### Weather Systems and Atmospheric Dynamics

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1211-02L</td>
<td>Master's Seminar: Atmosphere and Climate 2</td>
<td>O</td>
<td>3</td>
<td>2S</td>
<td>H. Joos, R. Knutti, A. Merrifield Könz, M. A. Wüest</td>
</tr>
</tbody>
</table>

**Abstract**

In this seminar, scientific project management is introduced and applied to the master projects. The course concludes with a presentation of all projects including an overview of the scientific content and a discussion of project management techniques related to the master thesis.

**Objective**

Apply scientific project management techniques to your master project, practice the presentation of scientific results and how to chair other students presentations and lead the discussion.

**Content**

In this seminar, scientific project management is introduced and applied to the master projects. The course concludes with a presentation of all projects including an overview of the scientific content and a discussion of project management techniques related to the master thesis.

**Prerequisites / notice**

Attendance is mandatory.

**Notice**

- **Weather Systems and Atmospheric Dynamics**

**Number** 651-4053-05L

**Title** Boundary Layer Meteorology

**Type** W

**ECTS** 4

**Hours** 3G

**Lecturers** M. Rotach, P. Calianca

**Abstract**

The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

**Objective**

Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts.

Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

**Content**

- Introduction
- Turbulence
- Statistical treatment of turbulence, turbulent transport
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Spectral characteristics
- Concepts for non-ideal boundary layer conditions

**Lecture notes**

available (i.e. in English)

**Literature**

- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

**Notice**

- Prior to participation in the course, students must have completed the following prerequisite courses:
  - Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

#### Climate Processes and Feedbacks

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<th>Number</th>
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<tbody>
<tr>
<td>701-1235-00L</td>
<td>Cloud Microphysics</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>U. Lohmann, N. Shardt</td>
</tr>
</tbody>
</table>

**Notice**

- Truck registration limit is 16.

Priority is given to PhD students majoring in Atmospheric and Climate Sciences, and remaining open spaces will be offered to the following groups:

- PhD students Environmental sciences
- MSc in Atmospheric and climate science
- MSc in Environmental sciences

All participants will be on the waiting list at first. Enrollment is possible until September 22nd, 2021. The waiting list is active until October 1st, 2021. All students will be informed on September 16th, if they can participate in the lecture.

The lecture takes place if a minimum of 5 students register!
Abstract
Clouds are a fascinating atmospheric phenomenon central to the hydrological cycle and the Earth’s climate. Interactions between cloud particles can result in precipitation, glaciation or evaporation of the cloud depending on its microstructure and microphysical processes.

Objective
The learning objective of this course is that students understand the formation of clouds and precipitation and can apply learned principles to interpret atmospheric observations of clouds and precipitation.

Content
see: http://www.iac.ethz.ch/edu/courses/master/modules/cloud-microphysics.html
and: https://moodle-app2.let.ethz.ch/course/view.php?id=15424

Lecture notes
This course will be designed as a reading course in 1-2 small groups of 8 students maximum. It will be based on the textbook below. The students are expected to read chapters of this textbook prior to the class so that open issues, fascinating and/or difficult aspects can be discussed in depth.

Literature
Lamb and Verlinde: PHYSICS AND CHEMISTRY OF CLOUDS, Cambridge University Press, 2011

Prerequisites / notice
Target group: Doctoral and Master students in Atmosphere and Climate

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories
assessed
Domain B - Method-specific Competencies
Analytical Competencies
assessed
Problem-solving
assessed
Domain C - Social Competencies
Communication
assessed
Domain D - Personal Competencies
Critical Thinking
assessed
Self-direction and Self-management
assessed

Atmospheric Composition and Cycles

Number
Title
Type
ECTS
Hours
Lecturers
701-1233-00L
Stratospheric Chemistry
W
4 credits
2V+1U
T. Peter, G. Chiodo

Abstract
The lecture gives an overview on the manifold reactions which occur in the gas phase, in stratospheric aerosol droplets and in polar cloud particles. The focus is on the chemistry of stratospheric ozone and its influence through natural and anthropogenic effects, especially the ozone depletion caused by FCKW in mid-latitude and polar regions as well as the coupling with the greenhouse effect.

Objective
The students will understand the gas phase reactions in the stratosphere as well as reactions and processes in aerosol droplets and polar stratospheric clouds. The students will understand the most important aspects of stratospheric dynamics and the greenhouse gas effect in troposphere and stratosphere.

Furthermore, they will also acquire a good understanding of the coupling between stratospheric ozone and climate change.

Content
Short presentation of thermodynamical and kinetic basics of chemical reactions: bi- and termolecular reactions, photo-dissociation. Introduction to the chemical family concept: active species, their source gases and reservoir gases. Detailed treatment of the pure oxygen family (odd oxygen) according to the Chapman chemistry. Radical reactions of the oxygen species with nitric oxide, active halogens (chlorine and bromine) and odd hydrogen. Ozone depletion cycles. Methane depletion and ozone production in the lower stratosphere (photo-smog reactions). Heterogeneous chemistry on the background aerosol and its significance for heavy air traffic. Chemistry and dynamics of the ozone hole: Formation of polar stratospheric clouds and chlorine activation.

Lecture notes
Documents are provided in the contact hours.

Literature

Prerequisites / notice
Prerequisites: Basics in physical chemistry are required and an overview equivalent to the bachelor course in atmospheric chemistry (lecture 701-0471-01) is expected.

701-1233-00 V starts in the first week of the semester. The exercises 701-1233-00 U will start only in the 2nd week of the semester.

701-1239-00L
Aerosols I: Physical and Chemical Principles
W
4 credits
2V+1U
M. Gysel Beer, D. Bell, E. Weingartner

Abstract
Aerosols I deals with basic physical and chemical properties of aerosol particles. The importance of aerosols in the atmosphere and in other fields is discussed.

Climate History and Paleoclimatology

Objective
The student will be able to describe the natural factors that lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
1. Overview of elements of the climate system and earth energy balance
2. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Palocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
3. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
4. Atmospheric circulation and variations in the earth's hydrological cycle - How variable are the earth's precipitation regimes? How large are the orbital scale variations in global monsoon systems? Will there be changes in El Nino frequency and intensity? What factors drive change in mid and high latitude precipitation systems? Is there evidence that changes in water availability have played a role in the rise, demise, or dispersion of past civilizations?
5. The Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

Hydrology and Water Cycle

Objective
Aims of the course:  The students will learn how to apply the basic concepts of hydrology and water cycle in a sustainable way. They will develop an understanding of the Earth's water cycle and the hydrological environment. They will be able to assess the importance of water resources in sustainable use and water conservation in different environments. They will be able to apply their knowledge of the hydrological cycle, water resources, and water management to real-world problems. They will be able to critically evaluate the impact of human activities on the hydrological cycle and water resources.

Content
- Overview of the Earth's Water Cycle
- Hydrological Processes
- Water Resources
- Water Management
- Impact of Human Activities on the Hydrological Cycle
- Sustainable Use of Water Resources

Lecture notes: material is distributed during the lecture

Literature:
Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. Students understand the theoretical foundations and probabilistic concepts of advanced analysis tools in meteorology and climatology. Literature consists of collections from standard hydrological textbooks and research papers, collected by the instructors on the course. There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise tasks.

The course introduces several advanced methods of statistical data analysis frequently used in meteorology and climatology. It introduces the theoretical background of the methods, illustrates their application with example datasets, and discusses complications from assumptions and uncertainties. Generally, the course shall empower students to conduct data analysis thoughtfully and to interpret results critically.

Topics covered: exploratory methods, hypothesis testing, analysis of climate trends, measuring the skill of deterministic and probabilistic predictions, analysis of extremes, principal component analysis and maximum covariance analysis.

The course is divided into lectures and computer workshops. Hands-on experimentation with example data shall encourage students in the practical application of methods and train professional interpretation of results.

R (a free software environment for statistical computing) will be used during the workshop. A short introduction into R will be provided during the course.

Lecture notes: Documentation and supporting material: - slides used during the lecture - exercise sets and solutions - R-packages with software and example datasets for workshop sessions

Literature: For complementary reading:

Prerequisites: Basics in exploratory data analysis, probability calculus and statistics (e.g. Mathematik IV: Statistik (401-0624-00L) and Mathematik VI: Angewandte Statistik für Umwelt naturwissenschaften (701-0105-00L)). Some experience in programming (ideally in R). Some elementary background in atmospheric physics and climatology.

Watershed Modelling is a practical course on numerical water balance models for a range of catchment-scale water resource applications. The course covers GIS use in watershed analysis, models types from conceptual to physically-based, parameter calibration and model validation, and analysis of uncertainty. The course combines theory (lectures) with a series of practical tasks (exercises).

The main aim of the course is to provide practical training with watershed models for environmental engineers. The course is built on thematic lectures (2 hrs a week) and practical exercises (2 hrs a week). Theory and concepts in the lectures are underpinned by many examples from scientific studies. A comprehensive exercise block build the lectures on the blocks with a series of 5 practical tasks to be conducted during the semester in group work. Exercise hours during the week focus on explanation of the tasks. The course is evaluated 60% by performance in the graded exercises and 40% by a semester-end oral examination (30 mins) on watershed modelling concepts.

Lecture notes: There is no textbook. Learning materials consist of (a) video-recording of lectures; (b) lecture presentations; and (c) exercise task documents that allow independent work.

Literature: Literature consists of collections from standard hydrological textbooks and research papers, collected by the instructors on the course moodle page.

Basic Hydrology in Bachelor Studies (engineering, environmental sciences, earth sciences). Basic knowledge of Matlab (Python), ArcGIS (Q-GIS).

Boundary Layer Meteorology: The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Objective: Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).
This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostrophic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and explained with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

The learning goals of this course are threefold: 1) obtain novel insight into an advanced scientific topic, 2) train the self-study competences with experts. The format of the course is complementary to other types of teaching (lectures and seminars) and addresses skills that are essential for a wide range of professional activities (including a PhD).

The course has the following elements:

Week 1: Selection of specific topic and decision about reading material (textbook chapters and maybe 1-2 review papers)
Week 2: General discussion about self-study skills (how to prepare efficient meetings). For the scientific writing, students are encouraged to participate in an online training course offered by Stanford University:
https://www.coursera.org/learn/sciwrite?action=enroll
Week 12: Hand-in of written summary (4 pages maximum)
Week 14: Supervisor provides written feedback to the summary document
Week 16: Oral exam about the scientific topic

Prerequisites depend on the chosen field and include successful completion of the listed lecture courses:
- atmospheric dynamics: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
- atmospheric chemistry: “Stratospheric Chemistry” (701-1233-00L) or “Tropospheric Chemistry” (701-1234-00L) or “Aerosols I” (402-0572-00L).
- atmospheric physics: “Atmospheric Physics” (701-0475-00L)
- climate physics: “Klimasysteme” (701-0412-00L) or equivalent
- land-climate dynamics: “Land-climate dynamics” (701-1251-00L)
- climate modeling; “Numerical modeling of weather and climate” (701-1216-00L) (parallel attendance possible)
- atmosphere circulation: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
- paleoclimate; “Climate History and Paleoclimate” (651-4057-00L).
- ocean biogeochemical dynamics: “Global Biogeochemical Cycles and Climate” (701-1317-00L)

If you plan to take this course, please contact one of the professors according to your interest.

- atmospheric chemistry (Prof. T. Peter)
- atmospheric dynamics (Prof. H. Wernli)
- atmospheric physics (Prof. U. Lohmann)
- climate modeling (Prof. C. Schär)
- climate physics (Prof. R. Knutti)
- land-climate dynamics (Prof. S. Schemm)
- atmospheric circulation (Prof. S. Schemm)
- paleoclimate (Prof. H. Stoll)
- ocean biogeochemical dynamics (Prof. N. Gruber)

This lecture course is about the fundamental aspects of the dynamics of extratropical weather systems (quasi-geostropic dynamics, potential vorticity, Rossby waves, baroclinic instability). The fundamental concepts are formally introduced, quantitatively applied and illustrated with examples from the real atmosphere. Exercises (quantitative and qualitative) form an essential part of the course.

- Concepts for non-ideal boundary layer conditions
- Spectral characteristics
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Turbulence
- Statistical treatment of turbulence, turbulent transport

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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<tbody>
<tr>
<td>701-1221-00L</td>
<td>Dynamics of Large-Scale Atmospheric Flow</td>
<td>W</td>
<td>4 credits</td>
<td>2V+1U</td>
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<th>Electives</th>
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| Weather Systems and Atmospheric Dynamics |

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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>701-1281-00L</td>
<td>Self-Learning Course on Advanced Topics in Atmospheric and Climate Science (HS)</td>
<td>W</td>
<td>3 credits</td>
<td>6A</td>
</tr>
</tbody>
</table>

- Students are allowed to enroll in both courses 701-1280-00L & 701-1281-00L Self-learning Course on Advanced Topics in Atmospheric and Climate Science but have to choose different supervisors.

<table>
<thead>
<tr>
<th>Literature</th>
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<th>Notice</th>
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- Literature (including book chapters, scientific publications) will be provided by the responsible supervisor in coordination with the student.

- Prerequisites depend on the chosen field and include successful completion of the listed lecture courses:

    - atmospheric dynamics: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
    - atmospheric chemistry: “Stratospheric Chemistry” (701-1233-00L) or “Tropospheric Chemistry” (701-1234-00L) or “Aerosols I” (402-0572-00L).
    - atmospheric physics: “Atmospheric Physics” (701-0475-00L)
    - climate physics: “Klimasysteme” (701-0412-00L) or equivalent
    - land-climate dynamics: “Land-climate dynamics” (701-1251-00L)
    - climate modeling; “Numerical modeling of weather and climate” (701-1216-00L) (parallel attendance possible)
    - atmosphere circulation: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
    - paleoclimate; “Climate History and Paleoclimate” (651-4057-00L).
    - ocean biogeochemical dynamics: “Global Biogeochemical Cycles and Climate” (701-1317-00L)

- If you plan to take this course, please contact one of the professors listed under prerequisites/notice if you plan to take this course.

- Please contact one of the professors listed under prerequisites/notice if you plan to take this course.

- Students are allowed to enroll in both courses 701-1280-00L & 701-1281-00L Self-learning Course on Advanced Topics in Atmospheric and Climate Science but have to choose different supervisors.
Objective
Understanding the dynamics of large-scale atmospheric flow

Content
Dynamical Meteorology is concerned with the dynamical processes of the earth's atmosphere. The fundamental equations of motion in the atmosphere will be discussed along with the dynamics and interactions of synoptic system - i.e. the low and high pressure systems that determine our weather. The motion of such systems can be understood in terms of quasi-geostrophic theory. The lecture course provides a derivation of the mathematical basis along with some interpretations and applications of the concept.

Lecture notes
Dynamics of large-scale atmospheric flow

Literature
- Pichler H., Dynamik der Atmosphäre, Bibliographisches Institut, 456 pp. 1997

Prerequisites / notice
Physics I, II, Environmental Fluid Dynamics

701-1257-00L European Climate Change

Abstract
The lecture provides an overview of climate change in Europe, from a physical and atmospheric science perspective. It covers the following topics:
• observational datasets, observation and detection of climate change;
• underlying physical processes and feedbacks;
• numerical and statistical approaches;
• currently available projections.

Objective
At the end of this course, participants should:
• understand the key physical processes shaping climate change in Europe;
• know about the methodologies used in climate change studies, encompassing observational, numerical, as well as statistical approaches;
• be familiar with relevant observational and modeling data sets;
• be able to tackle simple climate change questions using available data sets.

Content
Contents:
• global context
• observational data sets, analysis of climate trends and climate variability in Europe
• global and regional climate modeling
• statistical downscaling
• key aspects of European climate change: intensification of the water cycle, Polar and Mediterranean amplification, changes in extreme events, changes in hydrology and snow cover, topographic effects

Lecture notes
Slides and lecture notes will be made available at http://www.iac.ethz.ch/edu/courses/master/electives/european-climate-change.html

Prerequisites / notice
Participants should have a background in natural sciences, and have attended introductory lectures in atmospheric sciences or meteorology.

701-1281-00L Self-Learning Course on Advanced Topics in Atmospheric and Climate Science (HS)

Abstract
This course offers an individual pathway to deepen knowledge and understanding of a specific advanced topic in atmospheric and climate science in one of these fields:
- atmospheric chemistry
- atmospheric dynamics
- atmospheric physics
- climate modeling
- climate physics
- land-climate dynamics
- atmospheric circulation
- paleoclimate
- ocean biogeochemical dynamics

Objective
The learning goals of this course are threefold: 1) obtain novel insight into an advanced scientific topic, 2) train the self-study competences in particular related to reading of advanced textbooks and writing a concise summary, and 3) gain experience in the scientific interaction with experts. The format of the course is complementary to other types of teaching (lectures and seminars) and addresses skills that are essential for a wide range of professional activities (including a PhD).

Content
The course has the following elements:
Week 1: Selection of specific topic and decision about reading material (textbook chapters and maybe 1-2 review papers)
Week 2: General discussion about self-study skills (how to read scientific literature and write summaries; specifics of scientific writing; how to prepare efficient meetings). For the scientific writing, students are encouraged to participate in an online training course offered by Stanford University: https://www.coursera.org/learn/sciwrite?action=enroll
Weeks 6 and 9: Meetings with supervisor to clarify scientific questions
Week 12: Hand-in of written summary (4 pages maximum)
Week 14: Supervisor provides written feedback to the summary document
Week 16: Oral exam about the scientific topic

Literature
Literature (including book chapters, scientific publications) will be provided by the responsible supervisor in coordination with the student.
If you plan to take this course, please contact one of the professors according to your interest.

- atmospheric chemistry (Prof. T. Peter)
- atmospheric dynamics (Prof. H. Wernli)
- atmospheric physics (Prof. U. Lohmann)
- climate modeling (Prof. C. Schär)
- climate physics (Prof. R. Knutti)
- land-climate dynamics (Prof. S. Seneviratne)
- atmospheric circulation (Prof. S. Schemm)
- paleoclimate (Prof. H. Stoll)
- ocean biogeochemical dynamics (Prof. N. Gruber)

651-4057-00L Climate History and Palaeoclimatology

Abstract
Climate history and paleoclimatology explores how the major features of the earth's climate system have varied in the past, and the driving forces and feedbacks for these changes. The major topics include the earth's CO2 concentration and mean temperature, the size and stability of ice sheets and sea level, the amount and distribution of precipitation, and the ocean heat transport.

Objective
The student will be able to describe the natural factors lead to variations in the earth's mean temperature, the growth and retreat of ice sheets, and variations in ocean and atmospheric circulation patterns, including feedback processes. Students will be able to interpret evidence of past climate changes from the main climate indicators or proxies recovered in geological records. Students will be able to use data from climate proxies to test if a given hypothesized mechanism for the climate change is supported or refuted. Students will be able to compare the magnitudes and rates of past changes in the carbon cycle, ice sheets, hydrological cycle, and ocean circulation, with predictions for climate changes over the next century to millennia.

Content
1. Overview of elements of the climate system and earth energy balance
   a. The Carbon cycle - long and short term regulation and feedbacks of atmospheric CO2. What regulates atmospheric CO2 over long tectonic timescales of millions to tens of millions of years? What are the drivers and feedbacks of transient perturbations like at the latest Paleocene? What drives CO2 variations over glacial cycles and what drives it in the Anthropocene?
   b. Ice sheets and sea level - What do expansionist glaciers want? What is the natural range of variation in the earth's ice sheets and the consequent effect on sea level? How do cyclic variations in the earth's orbit affect the size of ice sheets under modern climate and under past warmer climates? What conditions the mean size and stability or fragility of the large polar ice caps and is their evidence that they have dynamic behavior? What rates and magnitudes of sea level change have accompanied past ice sheet variations? When is the most recent time of sea level higher than modern, and by how much? What lessons do these have for the future?
   5. Ocean heat transport - How stable or fragile is the ocean heat conveyor, past and present? When did modern deepwater circulation develop? Will Greenland melting and shifts in precipitation bands, cause the North Atlantic Overturning Circulation to collapse? When and why has this happened before?

>>> Atmospheric Composition and Cycles

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-1235-00L</td>
<td>Cloud Microphysics</td>
<td>W</td>
<td>4</td>
<td>2V+1U</td>
<td>U. Lohmann, N. Shardt</td>
</tr>
</tbody>
</table>

Priority is given to PhD students majoring in Atmospheric and Climate Sciences, and remaining open spaces will be offered to the following groups:
- PhD student Environmental sciences
- MSc in Atmospheric and climate science
- MSc in Environmental sciences

All participants will be on the waiting list at first. Enrollment is possible until September 22nd, 2021. The waiting list is active until October 1st, 2021. All students will be informed on September 16th, if they can participate in the lecture.

The lecture takes place if a minimum of 5 students register for it.

Abstract
Clouds are a fascinating atmospheric phenomenon central to the hydrological cycle and the Earth’s climate. Interactions between cloud particles can result in precipitation, glaciation or evaporation of the cloud depending on its microstructure and microphysical processes.

Objective
The learning objective of this course is that students understand the formation of clouds and precipitation and can apply learned principles to interpret atmospheric observations of clouds and precipitation.

Content

Lecture notes
This course will be designed as a reading course in 1-2 small groups of 8 students maximum. It will be based on the textbook below. The students are expected to read chapters of this textbook prior to the class so that open issues, fascinating and/or difficult aspects can be discussed in depth.

Literature
Lamb and Verlinde: PHYSICS AND CHEMISTRY OF CLOUDS, Cambridge University Press, 2011

Prerequisites / notice
Target group: Doctoral and Master students in Atmosphere and Climate
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Domain B - Method-specific Competencies</th>
<th>Domain C - Social Competencies</th>
<th>Domain D - Personal Competencies</th>
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<tbody>
<tr>
<td>Concepts and Theories</td>
<td>Analytical Competencies</td>
<td>Communication</td>
<td>Critical Thinking</td>
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</tr>
</tbody>
</table>

### 701-1281-00L Self-Learning Course on Advanced Topics in Atmospheric and Climate Science (HS)  

**W 3 credits 6A**  

**Supervisors**

Students are allowed to enroll in both courses 701-1280-00L & 701-1281-00L Self-learning Course on Advanced Topics in Atmospheric and Climate Science but have to choose different supervisors.

### Abstract

This course offers an individual pathway to deepen knowledge and understanding of a specific advanced topic in atmospheric and climate science in one of these fields:

- atmospheric chemistry  
- atmospheric dynamics  
- atmospheric physics  
- climate modeling  
- climate physics  
- land-climate dynamics  
- atmospheric circulation  
- paleoclimate  
- ocean biogeochemical dynamics

### Objective

The learning goals of this course are threefold: 1) obtain novel insight into an advanced scientific topic, 2) train the self-study competences in particular related to reading of advanced textbooks and writing a concise summary, and 3) gain experience in the scientific interaction with experts. The format of the course is complementary to other types of teaching (lectures and seminars) and addresses skills that are essential for a wide range of professional activities (including a PhD).

### Content

The course has the following elements:

**Week 1:** Selection of specific topic and decision about reading material (textbook chapters and maybe 1-2 review papers)  
**Week 2:** General discussion about self-study skills (how to read scientific literature and write summaries; specifics of scientific writing; how to prepare efficient meetings). For the scientific writing, students are encouraged to participate in an online training course offered by Stanford University:  
https://www.coursera.org/learn/sciwrite?action=enroll  
**Weeks 6 and 9:** Meetings with supervisor to clarify scientific questions  
**Week 12:** Hand-in of written summary (4 pages maximum)  
**Week 14:** Supervisor provides written feedback to the summary document  
**Week 16:** Oral exam about the scientific topic

### Literature

Literature (including book chapters, scientific publications) will be provided by the responsible supervisor in coordination with the student.

### Prerequisites / notice

Prerequisites depend on the successfull completion of the listed lecture courses:

- atmospheric dynamics: “Dynamics of large-scale atmospheric flow” (701-1221-00L)  
- atmospheric chemistry: “Stratospheric Chemistry” (701-1233-00L) or “Tropospheric Chemistry” (701-1234-00L) or “Aerosols I” (402-0572-00L)  
- atmospheric physics: “Atmospheric Physics” (701-0475-00L)  
- climate physics: “Klimasysteme” (701-0412-00L) or equivalent  
- land-climate dynamics: “Land-climate dynamics” (701-1251-00L)  
- climate modeling: “Numerical modeling of weather and climate” (701-1216-00L) (parallel attendance possible)  
- atmospheric circulation: “Dynamics of large-scale atmospheric flow” (701-1221-00L)  
- paleoclimate: “Climate History and Paleoclimate” (651-4057-00L)  
- ocean biogeochemical dynamics: “Global Biogeochemical Cycles and Climate” (701-1317-00L)

If you plan to take this course, please contact one of the professors according to your interest.

- atmospheric chemistry (Prof. T. Peter)  
- atmospheric dynamics (Prof. H. Wernli)  
- atmospheric physics (Prof. U. Lohmann)  
- climate modeling (Prof. C. Schär)  
- climate physics (Prof. R. Knutti)  
- land-climate dynamics (Prof. S. Seneviratne)  
- atmospheric circulation (Prof. S. Schemm)  
- paleoclimate (Prof. H. Stoll)  
- ocean biogeochemical dynamics (Prof. N. Gruber)

### 102-0635-01L Air Pollution Control  

**W 6 credits 4G**  

**J. Wang, B. Buchmann**

### Abstract

The lecture provides in the first part an introduction to the formation of air pollutants by technical processes, the emission of these chemicals into the atmosphere and their impact on air quality. The second part covers different strategies and techniques for emission reduction. The basic knowledge is deepened by the discussion of specific air pollution problems of today's society.

### Objective

The students gain general knowledge of the technical processes resulting in air pollution and study the methods used for air pollution control. The students can identify major air pollution sources and understand the methods for measuring pollutants, collecting and analyzing data. The students can suggest and evaluate possible control methods and equipment, design control systems and estimate their efficiency and efforts. The students know the different strategies of air pollution control and are familiar with their scientific fundamentals. They are able to incorporate goals concerning air quality into their engineering work.
Part 1 Emission, Immission, Transmission
Fluxes of pollutants and their environmental impact:
- physical and chemical processes leading to emission of pollutants
- mass and energy of processes
- Emission measurement techniques and concepts
- quantification of emissions from individual and aggregated sources
- extent and development of the emissions (Switzerland and global)
- propagation and transport of pollutants (transmission)
- meteorological parameters influencing air pollution dispersion
- deterministic and stochastic models, describing air pollution dispersion
- dispersion models (Gaussian model, box model, receptor model)
- measurement concepts for ambient air (immission level)
- extent and development of ambient air mixing ratios
- goal and instrument of air pollution control

Part 2 Air Pollution Control Technologies
The reduction of the formation of pollutants is done by modifying the processes (pro-cessintegrated measures) and by different engineering operations for the cleaning of waste gas (downstream pollution control). It will be demonstrated, that the variety of these procedures can be traced back to the application of a few basic physical and chemical principles.

Procedures for the removal of particles (inertial separator, filtration, electrostatic precipitators, scrubbers) with their different mechanisms (field forces, impaction and diffusion processes) and the modelling of these mechanisms.

Procedures for the removal of gaseous pollutants and the description of the driving forces involved, as well as the equilibrium and the kinetics of the relevant processes (absorption, adsorption as well as thermal, catalytic and biological conversions).

Discussion of the technical possibilities to solve the actual air pollution problems.

Lecture notes
Brigitte Buchmann, Air pollution control, Part I
Jing Wang, Air pollution control, Part II
Lecture slides and exercises

Literature
List of literature included in script
College lectures on basic physics, chemistry and mathematics.
Language of instruction: In German or in English.

651-4053-05L Boundary Layer Meteorology W 4 credits 3G M. Rotach, P. Calanca

Abstract
The Planetary Boundary Layer (PBL) constitutes the interface between the atmosphere and the Earth's surface. Theory on transport processes in the PBL and their dynamics is provided. The course starts by providing the theoretical background and reviewing idealized concepts. These are contrasted to real world applications and discussed in the context of current research issues.

Objective
Overall goals of this course are given below. Focus is on the theoretical background and idealized concepts. Students have basic knowledge on atmospheric turbulence and theoretical as well as practical approaches to treat Planetary Boundary Layer flows. They are familiar with the relevant processes (turbulent transport, forcing) within, and typical states of the Planetary Boundary Layer. Idealized concepts are known as well as their adaptations under real surface conditions (as for example over complex topography).

Content
- Introduction
- Turbulence
- Statistical tratment of turbulence, turbulent transport
- Conservation equations in a turbulent flow
- Closure problem and closure assumptions
- Scaling and similarity theory
- Spectral characteristics
- Concepts for non-ideal boundary layer conditions

Lecture notes
available (i.e. in English)

Literature

Prerequisites / notice
Umwelt-Fluiddynamik (701-0479-00L) (environment fluid dynamics) or equivalent and basic knowledge in atmospheric science

Climate History and Palaeoclimatology

Number Title Type ECTS Hours Lecturers
701-1281-00L Self-Learning Course on Advanced Topics in Atmospheric and Climate Science (HS) W 3 credits 6A Supervisors

Please contact one of the professors listed under prerequisites/notice if you plan to take this course.

Students are allowed to enroll in both courses 701-1280-00L & 701-1281-00L Self-learning Course on Advanced Topics in Atmospheric and Climate Science but have to choose different supervisors.

Abstract
This course offers an individual pathway to deepen knowledge and understanding of a specific advanced topic in atmospheric and climate science in one of these fields:
- atmospheric chemistry
- atmospheric dynamics
- atmospheric physics
- climate modeling
- climate physics
- land-climate dynamics
- atmospheric circulation
- paleoclimate
- ocean biogeochemical dynamics

Objective
The learning goals of this course are threefold: 1) obtain novel insight into an advanced scientific topic, 2) train the self-study competences in particular related to reading of advanced textbooks and writing a comprehensive summary, and 3) gain experience in the scientific interaction with experts. The format of the course is complementary to other types of teaching (lectures and seminars) and addresses skills that are essential for a wide range of professional activities (including a PhD).
The course has the following elements:

Week 1: Selection of specific topic and decision about reading material (textbook chapters and maybe 1-2 review papers)

Week 2: General discussion about self-study skills (how to read scientific literature and write summaries; specifics of scientific writing; how to prepare efficient meetings).

For the scientific writing, students are encouraged to participate in an online training course offered by Stanford University: https://www.coursera.org/learn/sciwrite?action=enroll

Weeks 6 and 9: Meetings with supervisor to clarify scientific questions

Week 12: Hand-in of written summary (4 pages maximum)

Week 14: Supervisor provides written feedback to the summary document

Week 16: Oral exam about the scientific topic

Literature (including book chapters, scientific publications) will be provided by the responsible supervisor in coordination with the student.

The sedimentary record of sea-level change

The students learn basic concepts of modern sedimentology and stratigraphy in the context of sequence stratigraphy and sea level change.

Details on the program will be handed out during the first lecture.

Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Quaternary Dating Methods

Reconstruction of time scales is critical for all Quaternary studies in both Geology and Archeology. Various methods are applied depending on the time range of interest and the archive studied. In this lecture, we focus on the last 50 ka and the methods that are most frequently used for dating Quaternary sediments and landforms in this time range.

Objective

Students will be made familiar with the details of the six dating methods through lectures on basic principles, analysis of case studies, solving of problem sets for age calculation and visits to dating laboratories.

At the end of the course students will:
1. understand the fundamental principles of the most frequently used dating methods for Quaternary studies.
2. be able to calculate an age based on data of the six methods studied.
3. choose which dating method (or combination of methods) is suitable for a certain field problem.
4. critically read and evaluate the application of dating methods in scientific publications.

Content

1. Introduction: Time scales for the Quaternary, Isotopes and decay
2. Radiocarbon dating: principles and applications
3. Cosmogenic nuclides: 3He, 10Be, 14C, 21Ne, 26Cl, 36Cl
4. U-series disequilibrium dating
5. Luminescence dating
6. Introduction to incremental: varve counting, dendrochronology and ice cores chronologies
7. Cs-137 and Pb-210 (soil, sediments, ice core)
8. Summary and comparison of results from several dating methods at specific sites

Prerequisites / notice

Visit to radiocarbon lab, cosmogenic nuclide lab, accelerator (AMS) facility.
Visit to Limno Lab and sampling a sediment core
Optional (individual): 1-5 days hands-on radiocarbon dating at the C14 lab at ETH Hoenggerberg

Required: attending the lecture, visiting laboratories, handing back solutions for problem sets (Exercises)

Hydrology and Water Cycle

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0535-00L</td>
<td>Environmental Soil Physics/Vadose Zone Hydrology</td>
<td>W</td>
<td>3 credits</td>
<td>2V+1U</td>
<td>A. Carminati, P. U. Lehmann Grunder</td>
</tr>
</tbody>
</table>

Abstract

The course provides theoretical and practical foundations for understanding and characterizing physical and transport properties of soils/near-surface earth materials, and quantifying hydrological processes and fluxes of mass and energy at multiple scales.

Objective

Students are able to
- characterize porous media at different scales
- parameterize structural, flow and transport properties of partially-saturated porous media
- quantify driving forces and resulting fluxes of water, solute, and heat in soils

Content

Week 1: Introduction, soil and vadose zone, units and dimensions, definitions and basic mass-volume relationships between the solid, liquid and gaseous phases; soil water content; soil texture; particle size distributions;
Week 2: Pore scale consideration, pore sizes, shapes and connectivity, definition number, continuity and percolation, surface area, soil structure
Week 3: Capillarity – capillary rise, surface tension, Young-Laplace equation; Washburn equation; numerical lab
Week 4: Soil Water Potential - the energy state of soil water; total water potential and its components; properties of water (molecular, surface tension, and capillary rise); units and calculations and measurement of equilibrium soil water potential components
Week 5: Soil water characteristics - definitions and measurements; parametric models, fitting and interpretation, hysteresis; demo lab
Week 6: Saturated water flow in soils - laminar flow in tubes (Poiseuille's Law); Darcy's Law, conditions and states of flow; permeability and hydraulic conductivity, measurement and theoretical concepts (Kozeny-Carman)
Week 7: Unsaturated water flow in soils - unsaturated hydraulic conductivity models and applications; Richards equation, approximations of Richards equation for steady state; approximate solutions to infiltration (Green-Ampt, Philip); outlook on unstable and preferential flow
Week 8: Numerical solution of Richards equation – using Hydrus1D for simulation of unsaturated flow; choosing class project
Week 9: Energy balance and land atmosphere interactions - radiation and energy balance; evapotranspiration, definitions and estimation; evaporation stages and characteristic length; soil thermal properties; steady state heat flow; non-steady heat flow
Week 10: Root water uptake and transpiration
Week 11: Solute and gas transport in soils; transport mechanisms of solutes in porous media; breakthrough curves; convection-dispersion equation; solutions for pulse and step solute application; parameter estimation; salt balance.
Week 12: Summary of lectures; solution of old exam
Week 13: Written semester-end exam
Week 14: Short presentations of Hydrus class projects; discussion of written exam

Literature

Supplemental textbook (not mandatory) - Introduction to Environmental Soil Physics, by: D. Hillel
Abstract
This course offers an individual pathway to deepen knowledge and understanding of a specific advanced topic in atmospheric and climate science in one of these fields:
- atmospheric chemistry
- atmospheric dynamics
- atmospheric physics
- climate modeling
- climate physics
- land-climate dynamics
- atmospheric circulation
- paleoclimate
- ocean biogeochemical dynamics

Objective
The learning goals of this course are threefold: 1) obtain novel insight into an advanced scientific topic, 2) train the self-study competences in particular related to reading of advanced textbooks and write concise summaries, and 3) gain experience in the scientific interaction with experts. The format of the course is complementary to other types of teaching (lectures and seminars) and addresses skills that are essential for a wide range of professional activities (including a PhD).

Content
The course has the following elements:
Week 1: Selection of specific topic and decision about reading material (textbook chapters and maybe 1-2 review papers)
Week 2: General discussion about self-study skills (how to read scientific literature and write summaries; specifics of scientific writing; how to prepare efficient meetings). For the scientific writing, students are encouraged to participate in an online training course offered by Stanford University:
https://www.coursera.org/learn/sciwrit?action=enroll
Weeks 6 and 9: Meetings with supervisor to clarify scientific questions
Week 12: Hand-in of written summary (4 pages maximum)
Week 14: Supervisor provides written feedback to the summary document
Week 16: Oral exam about the scientific topic

Literature
Literature (including book chapters, scientific publications) will be provided by the responsible supervisor in coordination with the student.

Prerequisites / notice
Prerequisites depend on the chosen field and include successful completion of the listed lecture courses:
- atmospheric dynamics: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
- atmospheric chemistry: “Stratospheric Chemistry” (701-1233-00L) or “Tropospheric Chemistry” (701-1234-00L) or “Aerosols I” (402-0572-00L)
- atmospheric physics: “Atmospheric Physics” (701-0475-00L)
- climate physics: “Klimasysteme” (701-0412-00L) or equivalent
- land-climate dynamics: “Land-climate dynamics” (701-1251-00L)
- climate modeling: “Numerical modeling of weather and climate” (701-1216-00L) (parallel attendance possible)
- atmospheric circulation: “Dynamics of large-scale atmospheric flow” (701-1221-00L)
- paleoclimate: “Climate History and Paleoclimate” (651-4057-00L)
- ocean biogeochemical dynamics: “Global Biogeochemical Cycles and Climate” (701-1317-00L)

If you plan to take this course, please contact one of the professors according to your interest.
- atmospheric chemistry (Prof. T. Peter)
- atmospheric dynamics (Prof. H. Wernli)
- atmospheric physics (Prof. U. Lohmann)
- climate modeling (Prof. C. Schär)
- climate physics (Prof. R. Knutti)
- land-climate dynamics (Prof. S. Seneviratne)
- atmospheric circulation (Prof. S. Schemm)
- paleoclimate (Prof. H. Stoll)
- ocean biogeochemical dynamics (Prof. N. Gruber)

102-0287-00L River Basin Erosion

Abstract
The course presents a view of the catchment processes of sediment production and transport that shape the landscape. Focus is on sediment fluxes from sources on hillslopes to the river network. Students learn about how a fluvial system functions, how to identify sediment sources and sinks, how to make predictions with numerical models, develop sediment budgets, and quantify geomorphic change.

Objective
The course has two fundamental aims: (1) The first aim is to provide environmental engineers with the physical process basis needed to understand fluvial system change, using the right language and terminology to describe landforms. We will cover the main geomorphic concepts of landscape change, e.g. thresholds, equilibrium, criticality, to describe change. Students will learn about the importance of the concepts of connectivity and timescales of change. (2) The second aim is to provide quantitative skills in making simple and more complex predictions of change and the data and models required. We will learn about typical landscape evolution models, and about hillslope erosion model concepts like RUSLE. We will learn how to identify sediment sources and sinks, and develop simulating sediment budgets with the right data needed for this purpose. Finally we will learn about methods to describe the topology of river networks as conduits of sediment through the fluvial system.

Content
The course consists of four sections: (1) Introduction to fluvial forms and processes and geomorphic concepts of landscape change, including climatic and human activities acting on the system. Concepts like thresholds, equilibrium, self-organised criticality, etc. are presented. (2) Landscape evolution modelling as a tool for describing the shape of the land surface. Soil formation and sediment production at long timescales. (3) The processes of sediment production, upland sheet-riparian erosion, basin sediment yield, rainfall-triggered landsliding, sediment budgets, and the modelling of the individual processes involved. Here we combine model concepts with field observations and look at many examples. (4) Processes in the river, floodplain and riparian zone, including river network topology, channel geometry, aquatic habitat, role of riparian vegetation, including basics of fluvial system management. The main focus of the course is on the hydrology-sediment connections at the field and catchment scale.

Prerequisites / notice
Prerequisites: Basic Hydrology and Watershed Modelling (or contact instructor).

651-2915-00L Seminar in Hydrology

Abstract
The course provides an introduction into quantitative analysis of groundwater flow and solute transport. It is focussed on understanding, formulating, and solving groundwater flow and solute transport problems.
Objective

a) Students understand the basic concepts of groundwater flow and solute transport processes, and boundary conditions.

b) Students are able to formulate simple, practical groundwater flow and solute transport problems.

c) Students are able to understand and apply simple analytical and/or numerical solutions to fluid flow and solute transport problems.

Content

1. Introduction to groundwater problems. Concepts to quantify properties of aquifers.

2. Flow equation. The generalised Darcy law.

3. The water balance equation and basic concepts of poroelasticity.


5. Analytical solutions to flow problems.

6. Finite difference scheme solution for simple flow problems.


10. Analytical solutions to transport problems.

11. Fractured and karst aquifers.

12. The unsaturated zone and capillary pressure.

13. Examples of applied hydrogeology from Switzerland and around the world. (Given by Dr. Beatrice Marti from Hydrosolutions Ltd.)

Lecture notes

Handouts of slides.

Literature


de Marsily G., Quantitative Hydrogeology, Academic Press, 1986

### Additional Elective Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1237-00L</td>
<td>Solar Ultraviolet Radiation</td>
<td>W</td>
<td>1</td>
<td>1V</td>
<td>J. Gröbner, S. Kazantzis</td>
</tr>
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</table>

Abstract

The lecture will introduce the student to the thematic of solar ultraviolet radiation and its effects on the atmosphere and the biosphere, as well as the retrieval of atmospheric trace gases. The lecture will also cover the modeling and the measurement of solar ultraviolet radiation.

Objective

- Effects of solar UV radiation on the Atmosphere, Humans, and the biosphere in general.
- Measurements of solar UV radiation (ground-based, satellite-based).
- Introduction to radiative transfer modelling, specifically for UV radiation.
- Methods to retrieve atmospheric constituents such as atmospheric ozone and aerosols from solar radiation measurements.
- Modelling of Solar UV radiation using satellite-based datasets.
The Lecture is composed of the following chapters:

1) Introduction and Motivation on the impact of solar UV radiation on the atmosphere, humans, and the biosphere in general.

2) Historical review of the scientific research.

3) Variability of solar UV radiation from a solar perspective (solar cycle, solar UV variabilty, impact on the higher atmosphere).

4) Understanding the variability of ground-based solar UV radiation with respect to the parameters influencing the transfer of solar UV radiation through the atmosphere.

5) Introduction to radiative transfer modeling, with emphasis on solar UV radiation.

6) Instruments to measure solar UV radiation

7) Retrieval of atmospheric trace gases from solar radiation measurements. Specific examples for retrieving atmospheric ozone, aerosols, and surface albedo.

8) Solar UV modelling over Europe at high spatial resolution using satellite-based datasets.

Lecture notes are based on the slides presented during the individual lectures. They will be handed out prior to the course via Moddle.

Prerequisites / notice

- Basic mathematical concepts such as Integration of spectral quantities.
- Familiar with a mathematical package such as R, Matlab, Python is advantageous for the calculation of the exercises.

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

Domain B - Method-specific Competencies

- Familiar with a mathematical package such as R, Matlab, Python is advantageous for the calculation of the exercises.
- Basic mathematical concepts such as Integration of spectral quantities.

Domain C - Social Competencies

- Understanding elements and principals of statistical learning
- Ability to select the appropriate statistical learning tools to tackle atmospheric and climate research problems
- Ability to apply methods of statistical learning to atmospheric and climate research
- Data in atmospheric and climate research (data types, observations, models)
- Exploring properties of atmospheric and climate data (data in space and time, multivariate data)
- Concepts of supervised learning (bias variance trade-off, overfitting, cross-validation)
- Advanced linear regression (multiple linear regression, regularization)
- Non-linear regression (tree based methods, neural networks)
- Un-supervised learning (dimension reduction, clustering)
- High-level applications of statistical learning for atmospheric and climate research (keynote speakers)

Domain D - Personal Competencies

- Programming (linear and nonlinear methods) and an overview of applications of statistical learning in the atmospheric and climate sciences.
- Understanding the variability of ground-based solar UV radiation with respect to the parameters influencing the transfer of solar UV radiation through the atmosphere.
- Instruments to measure solar UV radiation
- Data in space and time, multivariate data
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation
- Adaptability and Flexibility
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

701-1271-00L Statistical Learning for Atmospheric and Climate Science

Number of participants limited to 30.
Enrollment starts on September 20th, 2021.
Priority is given to the target groups: Master Environmental Science and Master Atmospheric and Climate Science until September 27th, 2021.
Waiting list will be deleted October 4th, 2021.

Abstract

The course will consist of overview lectures, hands-on practical exercises on (1) the basics of statistical learning and (2) with a focus on applications for atmospheric and climate science. Lectures will cover theoretical basics of statistical learning (advanced regression, nonlinear methods) and an overview of applications of statistical learning in the atmospheric and climate sciences.

Objective

- Understanding elements and principals of statistical learning
- Ability to select the appropriate statistical learning tools to tackle atmospheric and climate research problems
- Ability to apply methods of statistical learning to atmospheric and climate research
- Data in atmospheric and climate research (data types, observations, models)
- Exploring properties of atmospheric and climate data (data in space and time, multivariate data)
- Concepts of supervised learning (bias variance trade-off, overfitting, cross-validation)
- Advanced linear regression (multiple linear regression, regularization)
- Non-linear regression (tree based methods, neural networks)
- Un-supervised learning (dimension reduction, clustering)
- High-level applications of statistical learning for atmospheric and climate research (keynote speakers)

Literature


Prerequisites / notice

- Knowledge of introductory statistics
- Overview on the climate system
- Programming (linear and nonlinear methods) and an overview of applications of statistical learning in the atmospheric and climate sciences.

Course should be limited to 30 participants.

Exercises will be conducted in the R environment (https://www.r-project.org/), which is a specialized tool for statistical computing.

701-3001-00L Environmental Systems Data Science

W 3 credits 2G L. Pellissier, J. Payne, B. Stocker

701-3001-00L Statistical Learning for Atmospheric and Climate Science

W 3 credits 2G L. Gudmundsson, S. Sippel
## Numerical Modelling in Fortran

### Abstract
This course gives an introduction to programming in Fortran, and is suitable for students who have only minimal programming experience. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts.

### Objective
Fortran is a modern programming language that is updated every few years (most recently in 2018) and is specifically designed for scientific and engineering applications. This course gives an introduction to programming in this language, and is suitable for students who have only minimal programming experience, for example with MATLAB scripts. The focus will be on Fortran 95-2018, but differences to Fortran 77 will be mentioned for those working with already-existing codes. A hands-on approach will be emphasized rather than abstract concepts, using example scientific problems relevant to Earth science.

### Taught competencies

- **Domain A - Subject-specific Competencies**
  - Techniques and Technologies
  - Media and Digital Technologies
  - Problem-solving

- **Domain B - Method-specific Competencies**
  - 4 credits

### Prerequisites / notice

- 252-0940-02L Anwendungsnahe Programmieren mit Python
- 401-0624-00L Mathematik IV: Statistik
- 401-6215-00L Using R for Data Analysis and Graphics (Part I)
- 401-6217-00L Using R for Data Analysis and Graphics (Part II)
- 701-0050-00L Mathematik VI: Angewandte Statistik für Umwelt- und Naturwissenschaften

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### Biogeochemical Processes

#### Isotopes and Biomarkers in Biogeochemistry

**Abstract**
The course introduces the scientific concepts and typical applications of tracers in biogeochemistry. The course covers stable and radioactive isotopes, geochemical tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles. The course provides essential theoretical background for the lab course "Isotopic and Organic Tracers Laboratory".

**Objective**
The course aims at understanding the fractionation of stable isotopes in biogeochemical processes. Students learn to know the origin and decay modes of relevant radiogenic isotopes. They discover the spectrum of possible geochemical tracers and biomarkers, their potential and limitations and get familiar with important applications

**Content**
Geogenic and cosmogenic radionuclides (sources, decay chains); stable isotopes in biogeochemistry (natural abundance, fractionation); geochemical tracers for processes such as erosion, productivity, redox fronts; biomarkers for specific microbial processes.

**Lecture notes**
A list of relevant books and papers will be provided

**Prerequisites / notice**
Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

### Biogeochemical Trace Elements

**Abstract**
The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.

**Objective**
The students are familiar with the chemical characteristics, the environmental behavior and fate, and the biogeochemical reactivity of different groups of trace elements. They are able to apply their knowledge on the interaction of trace elements with geosphere components and on abiotic and biotic transformation processes of trace elements to discuss and evaluate the behavior and impact of trace elements in aquatic and terrestrial systems.

**Content**
(i) Definition, importance and biogeochemical classification of trace elements. (ii) Key biogeochemical processes controlling the cycling of different trace elements: redox-sensitive and chalcophile elements, volatile trace elements in natural and engineered environments. (iii) Abiotic and biotic processes that determine the environmental fate and impact of selected trace elements.
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences. This course explores the physics of fluids in the natural environment, with emphasis on the transport, dispersion, and mixing of solutes and entrained particles, and their implications for biological and biogeochemical processes.

Abstract
Fluid flows transport all manner of biologically important gases, nutrients, toxins, contaminants, spores and seeds, as well as a wide range of organisms themselves. This course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this course is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Lecture notes
The course is under development. Lecture materials will be distributed as they become available.

Applications

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1341-00L</td>
<td>Water Resources and Drinking Water</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Hug, M. Berg, F. Hammes, U. von Gunten</td>
</tr>
</tbody>
</table>

Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this course is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Lecture notes
The course is under development. Lecture materials will be distributed as they become available.

Prerequisites / notice
None

Literature
Will be mentioned in handouts

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<tr>
<th>Number</th>
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<tr>
<td>701-1346-00L</td>
<td>Nanomaterials in the Environment</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>N. Gruber</td>
</tr>
</tbody>
</table>

Abstract
The lecture provides an overview on the behavior and effects of engineered nanomaterials in the environment. The course will cover definitions, analysis, fate in technical and natural systems, effects (nano-ecotoxicology) and environmental risk assessment of nanomaterials. In addition, microplastics as an additional particulate contaminant will also be covered.

Objective
- Successful application of knowledge gained in the traditional disciplines of environmental sciences (e.g. biogeochemistry, environmental chemistry) to elucidate nanomaterial fate and behavior in the environment
- Identify key parameters of nanomaterials that potentially influence their environmental fate and behavior
- Get acquainted with the most common analytical tools for the quantification of nanomaterials in the environment
- Critical assessment of current state of research in this juvenile field, including the sometimes controversial literature data

Content
Topics
- Definitions; nano-effects; engineered, natural and incidental nanoparticles
- Sources and release; Material flow modeling
- Analysis in environmental samples
- Fate in technical systems: water treatment, waste incineration
- Fate in the environment: water and soil
- Effects: nano-ecotoxicology
- Environmental risk assessment
- Life cycle assessment
- Microplastics

Lecture notes
Handouts will be provided

Literature
Will be provided during lecture

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<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
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<tr>
<td>860-0012-00L</td>
<td>Cooperation and Conflict Over International Water Resources</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>B. Wehrli, T. Bernauer, E. Calamita, T. U. Siegfried</td>
</tr>
</tbody>
</table>

The lecture 701-1315-00L Biogeochemistry of Trace Elements is a prerequisite for attending the laboratory course 701-1331-00L Trace Elements Laboratory, or students must be concurrently enrolled in 701-1315-00L Biogeochemistry of Trace Elements in the same semester.
This is a research seminar at the Master level. PhD students are also welcome.

Abstract
This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Objective
Ability to (1) understand the causes and consequences of water scarcity and water pollution problems in large international river systems; (2) understand ways and means of addressing such water challenges; and (3) analyse when and why international efforts in this respect succeed or fail.

Content
Based on lectures and discussion of scientific papers and reports, students acquire basic knowledge on contentious issues in managing international water resources, on the determinants of cooperation and conflict over international water issues, and on ways and means of mitigating conflict and promoting cooperation. Students will then, in small teams coached by the instructors, carry out research on a case of their choice (i.e. an international river basin where riparian countries are trying to finn solutions to pollution and water quality problems associated with a large dam project). They will write a brief paper and present their findings towards the end of the semester.

Lecture notes
Slides and reading materials will be distributed electronically.

Literature
The UN World Water Development Reports provide a broad overview of the topic: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

Prerequisites / notice
The course is open to Master and PhD students from any area of ETH.

ISTP students who take this course should also register for the course 860-0012-01L - Cooperation and conflict over international water resources; In-depth case study.

Methods and Tools: Lab Courses

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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1331-00L</td>
<td>Biogeochemistry of Trace Elements Laboratory</td>
<td>W</td>
<td>3</td>
<td>4P</td>
<td>L. K. Thomas Arrigo, K. Barmettler</td>
</tr>
</tbody>
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Abstract
The course offers a practical introduction into the investigation of the biogeochemistry of trace elements. Laboratory experiments are performed to study a selected environmental process. Advanced techniques for the analysis of total element contents and element speciation are used. The experimental findings are interpreted and discussed in their environmental context.

Objective
The objective of this course, is to offer students a practical introduction into the investigation of the biogeochemistry of trace elements. During the course, students will become familiar with some of the key experimental approaches typically used in the investigation of the biogeochemistry of trace elements in the laboratory. In addition, students will learn to use different advanced analytical techniques to measure the total content and the speciation of trace elements in both liquid and solid samples. The students will interpret and discuss their experimental findings in the context of the studied environmental system.

Content
Laboratory experiments are designed and performed to study the interplay of various biogeochemical processes in a specific environmental system. Moreover, the effect of these processes on the biogeochemical cycling of trace elements in the environment will be considered. Advanced techniques for the analysis of total element contents and element speciation are used. The experimental findings are interpreted and discussed in the context of the studied environmental system.

Lecture notes
Selected handouts will be distributed during the course.

Literature
All necessary literature will be uploaded to the ILIAS repository during the course.

Prerequisites / notice
Pre- or corequisite: Lecture Biogeochemistry of Trace Elements.

701-1333-00L | Isotopes and Biomarkers in Biogeochemistry Laboratory | W    | 3    | 4P    | C. Schubert, R. Kipfer |

Abstract
This course will illustrate how different tracers and isotopes are used in natural systems. Here especially the processes (transformation, timescales) that take place and can be revealed by tracers/isotopes will be demonstrated but also flux rates will be calculated using different tracers.

Objective
Students know how to use tracers/isotopes to investigate/understand ecosystems
Have a feeling for timescales on which natural processes occur
Students will be able to apply different sampling techniques in aquatic sciences

Content
Basics:
O,H isotopes as tracers for mixing in aquatic systems
Carbon isotopes as tracer for methane oxidation
210Pb, 137Cs as a tracer for sedimentation rate/mixing
SF6, Neon, He as tracers for exchange processes at the air/water interface

Case assessment:
Sampling of a Swiss lake (Rotsee)
Sampling techniques for different elements
Sample preparation for different techniques
Measurements at iso/te mass spectrometer/gamma counter
Interpretation of results from the special sampling campaign and in a broader context.

701-1337-00L | Forest Soils in a Changing Environment | W    | 3    | 6P    | F. Hagedorn, P. F. Schleppi |

Abstract
The students are measuring carbon and nutrient fluxes in forest soils under a changing climate and land-use. In laboratory and field experiments, they are manipulating climatic conditions (temperature, drought) and quantify the response of C and N fluxes in soils, and plant-soil interactions. The results will be interpreted and discussed in the context of changes in climate and land-use.

Objective
The students get first-hand experience with field and laboratory methods to measure carbon and nutrient fluxes and the application of stable isotope techniques. They shall learn about physico-chemical properties of Swiss forest soils, how these properties determine the ecological functions of soils and how soils respond to changes in climate and land-use. Finally the students shall interpret, discuss and present their experimental data.
Content 1. Introduction to the ecological functions of Swiss forest soils 2. Measurement of soil CO2 efflux, carbon and nutrient leaching in forest and grassland soils 3. Sampling and preparation of litter and soil samples from selected soil profiles under different land-uses 4. Setting-up laboratory experiments in microcosms. Measurement of soil respiration and leaching of carbon, nutrients and/or contaminants in climate chambers under different environmental conditions. 5. Analyses of litter, soil, and soil water for selected physical and chemical properties. 6. Learning and applying stable isotope techniques for quantifying turnover of soil carbon and their microbial communities. 7. Interpretation and final presentation of data

Lecture notes A manual will be distributed during the course.

Literature Selected publications will be distributed during the course.

701-1339-00L Soil Solids Laboratory W 3 credits 4G M. Plötze

Number of participants limited to 12. Priority is given to the target groups: Master Environmental Science until October 15th, 2021. Waiting list will be deleted September 23rd, 2021.

Abstract The main part of the course is the investigation of real samples of soils/sediments in the lab working in groups. A brief theoretical introduction into the overall principle and the meaning of physical, mineralogical and chemical parameters of soils and sediments and into each analytical method for their investigation will be given in advance.

Objective Upon successful completion of this course students are able to:
- describe structural, mineralogical and chemical properties of the inorganic solid part of soils and sediments,
- propose and apply different advanced methods and techniques to measure these properties,
- critically assess the data and explain the relationships between them,
- communicate the results in a scientific la report.

Content Basic introduction to mineralogy and texture of soils Analytical techniques Practical exercises in sample preparation Measurement and evaluation of the data:
- physical parameters (grain size distribution, surface, densities, porosity, (micro)structure)
- mineralogical/geochemical parameters (quantitative mineralogical composition, thermal analysis, cation exchange etc.)

Lecture notes Selected handouts will be distributed during the course.


Prerequisites / notice In order to allow for effective lab work not more than 12 students can join the course.

Useful preparatory courses are: "Soil Chemistry", "Clays in Geotechnics", and "X-ray powder diffraction".

701-1673-00L Environmental Measurement Laboratory W 5 credits 4G P. U. Lehmann Grunder, A. Carminati

Number of participants limited to 24.

Waiting list will be deleted September 24th, 2021.

Abstract Measurements are the sole judge of scientific truth and provide access to unpredictable information, enabling the characterization and monitoring of complex terrestrial systems. Based on lectures and field- and laboratory training, the students learn to apply modern methods to determine forest inventory parameters and to measure subsurface properties and processes.

Objective The students will be able to:
- explain measurement principles that are used for characterization of landscapes and terrestrial systems
- select appropriate measurement methods and sampling design to quantify key variables and processes above ground and in the subsurface
- deploy sensors in the field
- interpret collected laboratory and field data and report main conclusions deduced from measurements

Content Week 1: Plant-Soil interactions – short introduction before sensor demonstration and installation in forest lab; Scholander pressure bomb (suction in leaves); LICOR soil chamber

Week 2: Lecture on Measurement Science, overview of water content and water potential sensors; data logging and data logger programming; tests in the lab

Week 3: Introduction on soil physics; Field installation of sensors and field experiment; data collection for a few days; solar panel

Week 4: Soil sampling in field lab including geoprobe measurements

Week 5: Introduction on forest lab - Soil sampling in forest lab; root length density;

Week 6: Lecture on geophysical methods on Subsurface Characterization: Basic principles of ERT, GPR, and EM; simple lab tests on effective resistivity

Week 7: Demonstration and application of geophysical methods in the field

Week 8: Lecture on plant soil relationship: connecting information below and above ground – data analysis

Weeks 9 and 10: Forest characterization/ inventory: Principles of LiDAR; structures and features of the tree crowns, size/volume of the leaf area tree positions and diameters at breast height

Weeks 11 and 12: Eddy covariance methods -Principles for field measurement of water vapor, carbon dioxide, and energy exchange between terrestrial surfaces and the atmosphere; Analysis of measured time series to determine evaporation rate and CO2-fluxes

Week 13: Swiss Soil Monitoring networks – Monitoring of soil water content and potential; climate change and droughts

Week 14: Global data – Global modeling and data interpretation; SoilGrids and OpenLandMap; exercises on Budyko analysis

Literature Lecture material will be online for registered students using moodle

Prerequisites / notice The details of the schedule will be optimized based on the number of students; some blocks of the course will be offered as well to students of Environmental Engineering.
The goal of the term paper seminars is to train the student's ability to communicate (scientific) results to a wider audience and the ability to critically evaluate original (scientific) literature and to summarise the information in a succinct manner is an important skill for research in the areas of biogeochemistry and pollutant dynamics.

Term Paper 1: Writing

Prerequisite: Term Paper 1: Writing (701-1303-00L).

Only for Environmental Sciences MSc and Science, Technology and Policy MSc.

Abstract
This class is the 2nd part of a series and participation is conditional on the successful completion of "Term Paper 1: Writing". The results from the term paper written during the previous term are presented to the other students and advisors and discussed with the audience.

Objective
The goal of the term paper seminars is to train the student's ability to communicate (scientific) results to a wider audience and the ability to respond to questions and comments.

Content
Each student presents the results of their term paper to fellow students and advisors and responds to questions and comments from the audience.

Lecture notes
Guidelines and supplementary material are distributed on the Moodle platform.

Prerequisites / notice
There is no final exam. Grade is assigned based on the quality of the presentation and ensuing discussion.

To obtain the credits, it is mandatory to attend at least 60% of all seminar dates offered in the fall and spring semester. Active participation in discussion and feedback rounds is expected.

Term Paper 2: Seminar

Prerequisite: Term Paper 1: Writing (701-1303-00L).

Only for Environmental Sciences MSc and Science, Technology and Policy MSc.

Abstract
The ability to critically evaluate original (scientific) literature and to summarise the information in a succinct manner is an important skill for any student. This course aims to practice this ability, requiring each student to write a term paper of scientific quality on a topic of relevance for research in the areas of biogeochemistry and pollutant dynamics.

Objective
The goal of the term paper is to train the student's ability to critically evaluate scientific literature and to summarise the findings concisely in a paper addressing a research question.

At the end of the course, students will be able to:
- narrow down a research question.
- identify relevant literature to address the research question.
- concisely summarise and critically evaluate their findings.
- formulate key outstanding questions.

Content
Each student is expected to write a paper with a length of approximately 15-20 pages. The students can choose from a list of topics prepared by the tutors, but the final topic will be determined based on a balance of choice and availability. The students will be guided and advised by their tutors throughout the term.

The paper itself should contain the following elements:
- Motivation and context of the given topic (25%)
- Concise presentation and critical evaluation of the state of the science (50%)
- Identification of open questions and perhaps opportunities for further research (25%)

In addition, the accurate use of citations, attribution of ideas, and the judicious use of figures, tables, equations and references are critical components of a successful paper. Specialised knowledge is not expected, nor required; neither is new research.

Lecture notes
Guidelines and supplementary material are distributed on the Moodle platform.

Literature
Original scientific literature will be identified based on the chosen topic.

Prerequisites / notice
Please enrol latest until the first week of the semester. Contact termpaper(at)env.ethz.ch if you don't yet have access to MyStudies.

The term paper course is primarily aimed at master students majoring in biogeochemistry & pollutant dynamics and ISTP students with a solid background in natural sciences and a strong interest in biogeochemistry & pollutant dynamics.

Each student submits a term paper that will be reviewed by one fellow student and one faculty. The submission of the term paper and a written review of another student's term paper are a condition for obtaining the credit points.

There is no final exam. The grade is assigned based on the quality of the term paper and the submitted review as well as on the presentation in the following term.

Results from the term paper will be presented to fellow students and involved faculty in the following semester ("Term Paper 2: Seminar").

Electives

Environmental Systems Data Science

Prerequisite: Term Paper 1: Writing (701-1303-00L).

Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to:
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Lecturers
L. Pellissier, J. Payne, B. Stocker
Content
- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Prerequisites / notice
- 252-0840-02L Anwendungsnahes Programmieren mit Python
- 401-0624-00L Mathematik IV: Statistik
- 401-6215-00L Using R for Data Analysis and Graphics (Part I)
- 401-6217-00L Using R for Data Analysis and Graphics (Part II)
- 701-0105-00L Mathematik VI: Angewandte Statistik für Umwelt naturwissenschaften

Major in Ecology and Evolution

A. Fundamentals

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<tr>
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<tr>
<td>701-0328-00L</td>
<td>Advanced Ecological Processes</td>
<td>W</td>
<td>4</td>
<td>2V</td>
<td>J. Hille Ris Lambers</td>
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For students of the following study programmes only: Biology Master
Teaching certificate Biology
Environmental Sciences Master
UZH MNF Biology
UZH MNF Geography /Earth Sciences

Abstract
This course presents the theoretical and empirical approaches used to understand the ecological processes structuring communities. Central problems in community ecology including the dynamics of species interactions, the influence of spatial structure, the controls over species invasions, and community responses to environmental change will be explored from basic and applied perspectives.

Objective
Students will understand how ecological processes operate in natural communities. They will appreciate how mathematical theory, field experimentation, and observational studies combine to generate a predictive science of ecological processes, and how this predictive science informs conservation and management decisions.

Upon completing the course, students will be able to:

- Understand the factors determining the outcome of species interactions in communities, and how this information informs management.
- Apply theoretical knowledge on species interactions to predict the potential outcomes of novel species introductions.
- Understanding the role of spatial structure in mediating population dynamics and persistence, species interactions, and patterns of species diversity.
- Use population and community models to predict the stability of interactions between predators and prey and between different competitors.
- Understand the conceptual basis of predictions concerning how ecological communities will respond to climate change.
- Discuss the types of conceptual advances ecology as a science can realistically achieve, and how these relate to the applications of the discipline.

Content
Lectures supplemented with readings from the primary literature and occasional computer exercises will focus on understanding central processes in community ecology. Topics will include demographic and spatial structure, consumer resource interactions, food webs, competition, mutualism, invasion, the maintenance of species diversity, and species effects on ecosystem processes. Each of these more conceptual topics will be discussed in concert with their applications to the conservation and management of species and communities in a changing world.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: not assessed

Domain B - Method-specific Competencies
- Analytical Competencies: assessed
- Decision-making: not assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed

Domain C - Social Competencies
- Communication: not assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: not assessed

Domain D - Personal Competencies
- Adaptability and Flexibility: not assessed
- Creative Thinking: assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-awareness and Self-reflection: not assessed
- Self-direction and Self-management: not assessed

701-1427-00L Experimental Evolution

Does not take place this semester. Semester change. This lecture will be offered in Spring Semester 2022 for the next time.

Abstract
Students will analyze experimental evolution literature covering a wide range of questions, species and types of analysis and will lead discussions of this literature. Students will develop a written project proposal for a novel evolution experiment (or a novel analysis of a published experiment) to address an unanswered question and will also deliver an oral presentation of the project proposal.
This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific evaluations and publications. It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess scientific literature.

Publications and class notes can be downloaded from a web page announced during the lecture. Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.

The three practicals will take place at the 05.10.2021, the 19.10.2021 and the 09.11.2021 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.

### B. Concept Courses and Applications

#### Advanced Concept Classes

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0263-01L</td>
<td>Seminar in Evolutionary Ecology of Infectious Diseases</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>R. R. Górs, S. Bonhoeffer</td>
</tr>
<tr>
<td>Abstract</td>
<td>Students of this course will discuss current topics from the field of infectious disease biology. From a list of publications, each student chooses some themes that he/she is going to explain and discuss with all other participants and under supervision. The actual topics will change from year to year corresponding to the progress and new results occurring in the field.</td>
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<tr>
<td>Objective</td>
<td>This is an advanced course that will require significant student participation. Students will learn how to evaluate and present scientific evaluations and publications. It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess scientific literature.</td>
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<tr>
<td>Content</td>
<td>A core set of ~10 classic publications encompassing unifying themes in infectious disease ecology and evolution, such as virulence, resistance, metapopulations, networks, and competition will be presented and discussed. Pathogens will include bacteria, viruses and fungi. Hosts will include animals, plants and humans.</td>
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<tr>
<td>Literature</td>
<td>Papers will be assigned and downloaded from a web page announced during the lecture.</td>
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<tr>
<td>Literature</td>
<td>Publications and class notes can be downloaded from a web page announced during the lecture.</td>
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<tbody>
<tr>
<td>701-1409-00L</td>
<td>Research Seminar: Ecological Genetics</td>
<td>W</td>
<td>2</td>
<td>1S</td>
<td>S. Fior</td>
</tr>
<tr>
<td>Abstract</td>
<td>In this research seminar we will critically discuss recent publications on current topics in Ecological Genetics.</td>
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<tr>
<td>Objective</td>
<td>It is our aim that participants gain insight into current research topics and approaches in Ecological Genetics and learn to critically assess and appreciate scientific publications in this field.</td>
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<tr>
<td>Lecture notes</td>
<td>none</td>
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<tr>
<td>Literature</td>
<td>will be distributed</td>
<td></td>
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<tr>
<td>Prerequisites / notice</td>
<td>Active and regular participation in the discussions, together with the presentation of a scientific paper are required to successfully pass this course. It is strongly recommended that participants have in advance successfully participated in the course Evolutionary Genetics (701-2413-00) or Ecological Genetics (701-1413-01).</td>
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<tbody>
<tr>
<td>701-1471-00L</td>
<td>Ecological Parasitology</td>
<td>W</td>
<td>3</td>
<td>1V+1P</td>
<td>J. Jokela, C. Vorburger</td>
</tr>
<tr>
<td>Abstract</td>
<td>Course focuses on the ecology and evolution of macroparasites and their hosts. Through lectures and practical work, students learn about diversity and natural history of parasites, adaptations of parasites, ecology of host-parasite interactions, applied parasitology, and human macroparasites in the modern world.</td>
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<tr>
<td>Objective</td>
<td>1. Identify common macroparasites in invertebrates.</td>
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<tr>
<td>Content</td>
<td>2. Understand ecological and evolutionary processes in host-parasite interactions.</td>
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<td></td>
<td>3. Conduct parasitological research</td>
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<td>Practical exercises:</td>
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<tr>
<td></td>
<td>1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).</td>
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<tr>
<td></td>
<td>2. Examination of parasites in amphipods (identification and examination of effects on hosts).</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The three practicals will take place at the 05.10.2021, the 19.10.2021 and the 09.11.2021 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.</td>
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<tbody>
<tr>
<td>701-1676-01L</td>
<td>Genomics of Environmental Adaptation</td>
<td>W</td>
<td>2</td>
<td>3G</td>
<td>R. Holderegger, F. Gugerli, C. Rellstab</td>
</tr>
<tr>
<td>Abstract</td>
<td>This five-day winter school aims at teaching advanced Master students, PhD students and post-doctoral researchers on aspects of the genomics of environmental adaptation. It provides both theoretical background and hands-on exercises on major topics of contemporary environmental genomics such as signatures of selection, outlier analysis or environmental association analysis.</td>
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**Notice:** Waiting list will be deleted on October 1st, 2021.
Attendees will learn which information is contained in genetic sequencing data and how to extract information from this data using computational tools. The main concepts introduced are:

- stochastic models in molecular evolution
- phylogenetic & phylodynamic inference
- maximum likelihood and Bayesian statistics

Attendees will apply these concepts to a number of applications yielding biological insight into:

- epidemiology
- pathogen evolution
- macroevolution of species

The aim of the course is to provide up-to-date knowledge on how we can study biological processes using genetic sequencing data. Computational algorithms extracting biological information from genetic sequence data are discussed, and statistical tools to understand this information in detail are introduced.

Abstract

Objective

Attendees will learn what environmental data are available and used to identify signatures of adaptation; what are their limitations; collinearity.

(1) How selection, drift, gene flow and isolation interact, affect neutral and adaptive genetic variation and influence the genetic structure of populations; genomic markers and next generation sequencing techniques.

(2) Outlier analysis: concept and methodology of outlier analysis; diverse types of outlier analyses

(3) Environmental data: which environmental data are available and used to identify signatures of adaptation; what are their limitations; collinearity.

(4) Environmental association analysis (landscape genomics): concept and types of environmental association analysis; genomic offset.

(5) Genotypes and phenotypes: GWAS; follow-up analyses

Waiting list will be deleted October 3rd, 2021.

Evolutionary Medicine for Infectious Diseases

Lecture notes

Literature

Grading will be according to a written report (6-8 pages), in which students will have to design a complete study in environmental genomics, and according to student contributions during the course.

Prerequisites: students must have good knowledge in population genetics and evolutionary biology and basic skills in R; experience with GIS is advantageous.

Number of participants limited to 36.

6 credits

Evolutionary Medicine

Evolutionary Parasitology

Evolutionary Medicine

636-0017-00L

Computational Biology

Computational Biology

Lecture notes

The course is not based on any of the textbooks below, but they are excellent choices as accompanying material:

- Drummond, A. & Bouckaert, R. 2015. Bayesian evolutionary analysis with BEAST.
Prerequisites / notice
Basic knowledge in linear algebra, analysis, and statistics will be helpful. Programming in R will be required for the project work (compulsory continuous performance assessments). We provide an R tutorial and help sessions during the first two weeks of class to learn the required skills. However, in case you do not have any previous experience with R, we strongly recommend to get familiar with R prior to the semester start. For the D-BSSE students, we highly recommend the voluntary course 'Introduction to Programming', which takes place at D-BSSE from Wednesday, September 12 to Friday, September 14, i.e. BEFORE the official semester starting date http://www.cbb.ethz.ch/news-events.html
For the Zurich-based students without R experience, we recommend the R course http://www.vzv.ethz.ch/Vorlesungsverzeichnis/lerneinheit/view?semkez=2018W&ansicht=KATALOGDATEN&lerneinheitId=123546&lang=d e, or working through the script provided as part of this R course.

751-5101-00L Biogeochemistry and Sustainable Management
Does not take place this semester.

Abstract
This course focuses on the interactions between ecology, biogeochemistry and management of agro- and forest ecosystems, thus, coupled human-environmental systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Objective
Students will analyse and understand the complex and interacting processes of ecology, biogeochemistry and management of agroecosystems, be able to analyze large meteorological and flux data sets, and evaluate the impacts of weather events and management practices, based on real-life data. Moreover, students will be able to coordinate and work successfully in small (interdisciplinary) teams.

Content
Agroecosystems play a major role in all landscapes, either for production purposes, ecological areas or for recreation. The human impact of any management on the environment is mainly driven by effects on biogeochemical cycles. Effects of global change impacts will also act via biogeochemistry at the soil-biosphere-atmosphere-interface. Thus, ecosystem functioning, i.e., the interactions between ecology, biogeochemistry and management of terrestrial systems, is the science topic for this course.

Students will gain profound knowledge about biogeochemical cycles and greenhouse gas fluxes in managed grassland and/or cropland ecosystems. Responses of agroecosystems to the environment; i.e., to climate and weather events, but also to management will be studied. Different meteorological and greenhouse gas flux data will be analysed (using R) and assessed in terms of production, greenhouse gas budgets and carbon sequestration. Thus, students will learn about the complex interactions of a coupled human-environmental system.

Students will work with real-life data from the long-term measurement network Swiss FluxNet. Data from the intensively managed grassland site Chamau will be used to investigate the biosphere-atmosphere exchange of CO2, H2O, N2O and CH4. Functional relationships will be identified, greenhouse gas budgets will be calculated for different time periods and in relation to management over the course of a year.

Lecture notes
Handouts will be available on the webpage of the course.

Literature
Will be discussed in class.

Prerequisites / notice
Prerequisites: Attendance of introductory courses in plant ecophysiology, ecology, and grassland or forest sciences. Knowledge of data analyses in R and statistics. Course will be taught in English.

Applications

<table>
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<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
<tbody>
<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3 credits</td>
<td>3G</td>
<td>F. Knaus</td>
</tr>
<tr>
<td>710-1613-01L</td>
<td>Advanced Landscape Research</td>
<td>W</td>
<td>5 credits</td>
<td>3G</td>
<td>J. Bolliger, M. Bürgi, U. Gimmi, M. Hunziker</td>
</tr>
</tbody>
</table>

Autumn Semester 2021

This course introduces the broad variety of conflicts that arise in projects focusing on sustainable management of natural resources. It encompassing concepts and approaches.

1. Encompassing concepts and approaches
   - green infrastructure (e.g., ecological conservation areas)
   - landscape connectivity
   - concepts of specific quantitative methods: least cost paths, resistance surfaces, Circuitscape, networks (Conefor), land-use change models, various statistical methods

2. Ecological approach:
   - landscape genetics and management applications

3. Social-science approach:
   - theories on landscape preference and place identity
   - role of landscapes for recreation, health and well-being
   - methods of investigating the human-landscape relationship and evaluating interventions

4. Historical approach:
   - land use history of Switzerland (agricultural history, forest and woodland history)
   - historical legacies of land use in landscapes and ecosystems
   - historic-ecological approaches and applications

5. Land change science:
   - modelling future land-use (CLUE, other scenario-based models)
   - landscape functions and services

Objectives

Students should be able to

a) propose appropriate and realistic solutions to ecosystem management problems that integrate ecological, economic and social dimensions across relevant temporal and spatial scales,

b) identify important stakeholders, their needs and interests, and the main conflicts that exist among them in the context of land and resource management.

Content

Traditional management systems focus on extraction of natural resources, and their manipulation and governance. However, traditional management has frequently resulted in catastrophic failures such as, for example, the collapse of fish stocks and biodiversity loss. These failures have stimulated the development of alternative ecosystem management approaches that emphasise the functionality of human-dominated systems. Inherent to such approaches are system-wide perspectives and a focus on ecological processes and services, multiple spatial and temporal scales, as well as the need to incorporate diverse stakeholder interests in decision making. Thus, ecosystem management is the science and practice of managing natural resources, biodiversity and ecological processes, to meet multiple demands of society. It can be local, regional or global in scope, and addresses critical issues in developed and developing countries relating to economic and environmental security and sustainability.

This course provides an introduction to ecosystem management, and in particular the importance of integrating ecology into management systems to meet multiple societal demands. The course explores the extent to which human-managed terrestrial systems depend on underlying ecological processes, and the consequences of degradation of these processes for human welfare and environmental well-being. Building upon a theoretical foundation, the course will tackle issues in resource ecology and management, notably forests, agriculture and wild resources within the broader context of sustainability, biodiversity conservation and poverty alleviation or economic development. Case studies from tropical and temperate regions will be used to explore these issues. Dealing with ecological and economic uncertainty, and how this affects decision making, will be discussed. Strategies for conservation and management of terrestrial ecosystems will give consideration to landscape ecology, protected area systems, and community management, paying particular attention to alternative livelihood options and marketing strategies of common pool resources.

Lecture notes

No Script

Literature

The course provides the student with the spatial tools to address societal challenges toward ensuring the sustainable use of terrestrial ecosystems and the conservation of biodiversity. Students learn theory, tools and models during a few introductory sessions and apply this knowledge to solve a practical problem in groups related to climate change, land use change and biodiversity conservation.

**Objective**

- Theoretical foundations of the species ecological niche
- Biodiversity concepts and global change impacts
- Basic concepts of spatial (geo-)ecology
- Environmental impact assessment and planning
- Advanced statistical methods (GLM, GAM, CART) and basic programming (loops, functions, advanced scripting) in the statistical environment R.
- The use of GIS functionality in R

**Content**

1. The basics:
   - Introduction to the concept of the ecological niche, and biodiversity theories. Overview of the knowledge on expected biodiversity response to global changes and conservation planning methods.
   - Introduction to the statistical methods of Generalized Linear (GLM) and Generalized Additive models (GAM), and Classification and Regression Trees (CART). Introduction to basic GIS and programming elements in the statistical environment R.

2. The class project:
   - Students form groups of two, and each group solves a series of applied questions independently in R using the techniques taught in the introductory classes. The students then prepare a presentation and report of the obtained results that will be discussed during a mini-symposium. Each team choses one of the following topics for the class project:
     a) Linking climate change velocities to species’ migration capacities
     b) Explaining and modelling biodiversity changes in Switzerland
     c) Explaining and modelling land use change in Switzerland
     d) Designing biodiversity conservation strategies under global changes.

**Prerequisites / notice**

Basic knowledge in statistics (OLS regression, test statistics), and basic knowledge in geographic information science.

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### Laboratory and Field Expertise

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<tr>
<th>Number</th>
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<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1425-01L</td>
<td>Genetic Diversity: Techniques</td>
<td>W</td>
<td>2 credits</td>
<td>4P</td>
<td>A. M. Minder Pfyl</td>
</tr>
</tbody>
</table>

Waiting list will be deleted November 1st, 2021.

**Abstract**

This course provides training for advanced students (master, doctoral or post-doctoral level) in how to measure and collect genetic diversity data from populations, experiments, field and laboratory. Different DNA/RNA extraction protocols, quality control measurements, SNP genotyping and gene expression techniques will be addressed.

**Objective**

To learn and improve on standard and modern methods of genetic data collection. Examples are: use of pyrosequencing, expression analysis, SNP-typing, next-generation sequencing etc.

A course for practicioners.

**Content**

- After an introduction (one afternoon), students will have 3 weeks to work independently in groups of two through different protocols. At the end the whole class meets for another afternoon to present the techniques/results and to discuss the advantages and disadvantages of the different techniques.
- Techniques addressed are: DNA/RNA extractions and quality control, SNP genotyping, pyrosequencing, real-time qPCR.

**Lecture notes**

Material will be handed out in the course.

**Literature**

Material will be handed out in the course.

**Prerequisites / notice**

Two afternoons are hold in the class. The lab work will be done from the students according to their timetable, but has to be finished after 3 weeks. Effort is roughly 1-2 days per week, depending on the skills of the student.

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<tr>
<td>701-1437-00L</td>
<td>Aquatic Ecology I</td>
<td>W</td>
<td>3 credits</td>
<td>3V</td>
<td>P. Spaak, F. Altermatt, A. Narwani, C. T. Robinson</td>
</tr>
</tbody>
</table>

**Abstract**

This course combines Limnology (the study of inland waters in its broad sense) with ecological and evolutionary concepts. It deals with river, groundwater and lakes.

**Objective**

During this course you will get an overview of the world’s typical freshwater ecosystems. After this course you will be able to understand how aquatic organisms have adapted to their habitat and how the interactions (e.g. food web) between organisms work.

In short: apply the theoretical / lecture knowledge to field situations in a lake and river.
The lectures cover ecology and evolution of aquatic organisms in lentic and lotic waters. Topics include: Adaptations, distribution patterns, biotic interactions, and conceptual paradigms in freshwater ecosystems. Important aspects regarding ecosystem metabolism and habitat properties of freshwaters. Applied case studies and experiments testing ecological and evolutionary processes in freshwaters.

The lectures are given by Piet Spaak (Eawag), Florian Altermitt (UNI, Eawag), Chris Robinson (Eawag), Francesco Pomati (Eawag), Anita Narwani (Eawag) and specialists from the Aquatic Ecology department of Eawag and University of Zurich.

Course notes and power point presentations provided during the course.

701-1437-03L Aquatic Ecology II
Number of participants is limited. The maximal participating number of students is 8 from D-USYS and 14 from D-BIOL (ETH & UZH).
Target groups only: Bachelor Biology, Master Environmental Sciences and UZH MNF Biology.

Registration for the course until September 5th, 2021, free places will be distributed later. Students registering later cannot be guaranteed a place in the course. Waiting list will be deleted September 17th, 2021.
Students have to enroll together with the lecture Aquatic Ecology I (701-1437-00V) and the Identification Courses Macroinvertebrates (701-1437-01L) and Freshwater Algae and aquatic Microinvertebrates (701-1437-02L).

Abstract
This course builds on Aquatic Ecology I and cannot be taken separately. It aims on extending the covered concepts and apply them to natural and experimental systems.

Objective
During the research project you will learn the principles of doing research to observe interrelations in aquatic ecosystems. You will measure and interpret biological and physical data (e.g. during experiments, field work). You will present the collected knowledge and write a report about it.

Content
During the excursions you will get to know a lake system as well as a river system. The main goal of the excursions is that the students as a team conduct their own field research project and collect data in the field.

Lecture notes
Course notes and power point presentations provided during the course.

Prerequisites / notice
This course can only be taken together with "701-1437-00 Aquatic Ecology I", "701-1437-01 Bestimmungskurs aquatische Makroinvertebraten" and "701-1437-02 Bestimmungskurs Süßwasseralgen und aquatische Mikroinvertebraten".

The maximal participating number of students is 8 from D-USYS and 14 from D-BIOL (ETH & UNI).
Registration for the course until 26.08.2021, free places will be distributed after that. Students registering later cannot be guaranteed a place in the course.

The course includes a mandatory field trip to Greifensee (23.09.2021) and a three-day excursion to the river Glatt (29.09. bis 01.10. 2021).

Expertise in Biological Diversity

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<th>Number</th>
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<tr>
<td>701-1437-01L</td>
<td>Practical Course Macroinvertebrates</td>
<td>W</td>
<td>2</td>
<td>2P</td>
<td>J. Jokela</td>
</tr>
<tr>
<td>Abstract</td>
<td>This course gives an overview of the typical aquatic macroinvertebrate groups in Switzerland. Beside a theoretical background on the different groups the focus is laid on the determination of the most important species groups and their identification traits, also using identification keys. Practical experience in benthic sampling techniques is collected during an excursion.</td>
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<tr>
<td>Objective</td>
<td>During this course you will get an overview of the typical aquatic macroinvertebrates in Switzerland and the common sampling techniques. After this course you will be able to identify the most important aquatic species groups at the level of order/family and know the most important identification traits. You will also be able to use identification literature commonly used in Switzerland.</td>
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<tr>
<td>Content</td>
<td>The taxonomic part will cover macroinvertebrates (e.g. Crustacean, aquatic insects). The goal is to get to know the most common aquatic taxa in Switzerland, to identify them with commonly used identification literature, and to get an idea how these organisms are used in research and practice. (language: German, translation of the most important things during the course possible)</td>
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<tr>
<td>Lecture notes</td>
<td>Course notes and power point presentations provided during the course.</td>
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<tr>
<td>Prerequisites / notice</td>
<td>The maximal participating number of students is 8 from D-USYS and 14 from D-BIOL. In case of too many students, those that simultaneously participate in the courses &quot;701-1437-00 Aquatic Ecology I&quot; and &quot;701-1437-01 Bestimmungskurs aquatischer Makroinvertebraten&quot; are given priority. Sign in until 26.08.2021, free places will be distributed after that. Students registering later cannot be guaranteed a place in the course.</td>
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<tr>
<td>The field excursion takes place Tuesday 26.10.2021.</td>
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<tr>
<td>The field excursion takes place Tuesday afternoon 26.10.2021 from 1pm-5pm.</td>
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| 701-1437-02L | Identification Course Freshwater Algae and Aquatic Microinvertebrates | W    | 2    | 2P    | J. Jokela            |
| Abstract    | This course gives an overview of the typical aquatic microinvertebrate and freshwater algae groups in Switzerland. Beside a theoretical background of the different groups the focus is laid on the recognition of the most important species groups and their identifiation traits. Practical experience is collected during an excursion. |
| Objective   | During this course you will get an overview of the typical aquatic microinvertebrates and algae in Switzerland. After this course you will know the most important aquatic species groups and the most important identification traits. You will apply the theoretical knowledge during an excursion. |
| Content     | The taxonomic part will cover microinvertebrates and freshwater algae. The goal is to get to know the most common aquatic taxa in Switzerland, to identify them and to get an idea how these organisms are used in research and practice. (language: German, translation of the most important things during the course possible) |
| Lecture notes | Course notes and power point presentations provided during the course. |
| Prerequisites / notice | The maximal participating number of students is 8 from D-USYS and 14 from D-BIOL. In case of too many students, those that simultaneously participate in the courses "701-1437-00 Aquatic Ecology I" and "701-1437-01 Bestimmungskurs aquatischer Makroinvertebraten" are given priority. Sign in until 26.08.2021, free places will be distributed after that. Students registering later cannot be guaranteed a place in the course. |
| The field excursion takes place Thursday 21.10.2021 from 1pm-5pm. |
The students are able to
Topics for the essays are proposed by the professors and lecturers of the major in Ecology and Evolution at a joint meeting at the beginning of the semester (the date will be communicated by e-mail to registered students).
Students will:
- choose a topic
- search and read appropriate literature
- develop a personal view on the topic and structure their arguments
- prepare figures and tables to represent ideas or illustrate them with examples
- write a clear, logical and well-structured text
- refine the text and present the paper according to professional standards

In all steps, they will benefit from the advice and detailed feedback given by a senior scientist acting as personal tutor of the student.

Lecture notes
Reading of articles in scientific journals

- Students acquire a thorough knowledge on a topic in which they are particularly interested
- They learn to assess the relevance of original literature and synthesize information
- They make the experience of becoming "experts" on a topic and develop their own perspective
- They practise academic writing according to professional standards in English

ECTS
- Students acquire a thorough knowledge on a topic in which they are particularly interested

- Self-direction and Self-management

- Developing presentation and discussion skills

- Working in interdisciplinary teams on the topics

- Developing presentation and discussion skills

- Introduction to recent research in all fields of plant sciences

- Working in interdisciplinary teams on the topics

- Developing presentation and discussion skills

- The topics encompass integrated knowledge on current plant research, ranging from the molecular level to the ecosystem level, and from basic to applied science while making use of the synergies between the different research groups within the PSC.

More information on the content: https://www.plantsciences.uzh.ch/en/teaching/masters/colloquium.html

Abstract
Ecology and Evolution: Term Paper

Study of the environmental and evolutionary processes in plant systems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the development of epidemics in agroecosystems.

Students will:
- choose a topic
- search and read appropriate literature
- develop a personal view on the topic and structure their arguments
- prepare figures and tables to represent ideas or illustrate them with examples
- write a clear, logical and well-structured text
- refine the text and present the paper according to professional standards

In all steps, they will benefit from the advice and detailed feedback given by a senior scientist acting as personal tutor of the student.

Lecture notes
Reading of articles in scientific journals

Subject-specific Competencies

- Domain A - Subject-specific Competencies
- Domain B - Method-specific Competencies
- Domain C - Social Competencies
- Domain D - Personal Competencies

Cooperation and Teamwork

Self-direction and Self-management

Autumn Semester 2021
Page 2096 of 2152
Objective
Students will understand: 1) how pathogens attack plants and; 2) how plants defend themselves against pathogens; 3) factors driving the
development of epidemics in agroecosystems as a basis for implementing disease management strategies in agroecosystems.

Content
Course description: Plant Pathology I will focus on pathogen-plant interactions, epidemiology, disease assessment, and disease
development in agroecosystems. Themes will include: 1) how pathogens attack plants and; 2) how plants defend themselves against
pathogens; 3) factors driving the development of epidemics in agroecosystems. Topics under the first theme will include pathogen life
cycles, disease cycles, and an overview of plant pathogenic nematodes, viruses, bacteria, and fungi. Topics under the second theme will
include plant defense strategies, host range, passive and active defenses, and chemical and structural defenses. Topics under the third
theme will include the disease triangle and cultural control strategies.

Lecture Topics and Tentative Schedule

Week 1  The nature of plant diseases, symbiosis, parasites, mutualism, biotrophs and necrotrophs, disease cycles and pathogen life
cycles.
Week 2  Nematode attack strategies and types of damage. Viral pathogens, classification, reproduction and transmission, attack
strategies and types of damage. Examples TMV, BYDV. Bacterial pathogens and phytoplasmas, classification, reproduction and
transmission.
Week 3  Bacterial attack strategies and symptoms. Example bacterial diseases: fire blight, Agrobacterium crown gall, soft rots. Fungal
and oomycete pathogens, classification, growth and reproduction, sexual and asexual spores, transmission.
Week 4  Fungal and oomycete life cycles, disease cycles, infection processes, colonization, phytotoxins and mycotoxins. Attack
strategies of fungal necrotophs and biotrophs. Symptoms and signs of fungal infection. Example fungal diseases: potato late blight.
Week 5  Example fungal diseases: wheat stem rust, grape powdery mildew, wheat septoria tritici blotch. Plant defense mechanisms, host
range and non-host resistance. Passive structural and chemical defenses, preformed chemical defenses. Active structural defense,
histological and cellular (papillae).
Week 6  Active chemical defense, hypersensitive response, pathogenesis-related (PR) proteins, phytoalexins and disease resistance.
Pisatin and pisatin demethylase. Local and systemic acquired resistance (LAR, SAR), induced systemic resistance (ISR), signal molecules,
defense activators (Bion). Pathogen effects on food quality. Positive and negative transformations.
Week 7  Negative pathogen impacts on crop yield and quality. Pathogen effects on food safety. Mycotoxins in the food chain. Aflatoxin,
patulin safety assessment and action thresholds. Epidemiology: historical epidemics.
Week 8  Epidemiology: Disease pyramid, environmental effects on epidemic development, plant effects on development of epidemics,
including resistance, physiology, density, uniformity.
Week 9  Disease assessment: incidence and severity measures, keys, diagrams, scales, measurement errors. Correlations between
incidence and severity. Molecular detection and diagnosis of pathogens. Host indexing, serology, monoclonal and polyclonal antibodies,
ELISA.
Week 10 Molecular detection and diagnosis of pathogens: PCR, rDNA and loop-mediated isothermal amplification. Strategies for
minimizing disease risks: calculating disease thresholds, disease forecasting systems.
Week 11 Strategies for minimizing disease risks: lowering epidemic risk, ecological risk assessment, natural and synthetic pesticides.
Disease control strategies: economic thresholds, overview of control strategies.
Week 12 Physical control methods. Cultural control methods: avoidance, tillage practices, crop sanitation.
Week 13 Cultural control methods: fertilizers, crop rotations.
Week 14 Open lecture.

Lecture notes
Detailed lecture notes (~160 pages) will be available for purchase at the cost of reproduction at the start of the semester.

Major in Environmental Systems Policy
Theoretical Foundations for Environmental Policy

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
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<tr>
<td>701-1563-00L</td>
<td>Climate Policy</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>A. Patt, S. Hanger-Kopp</td>
</tr>
</tbody>
</table>

This course provides an in-depth analysis of the theoretical underpinnings to different approaches to climate policy at the
international and national levels, and how these different approaches have played out in practice. Students will learn how legislative
frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

Objective
Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 30 to 40 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because it means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, but even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that governments ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

This course is about all that. The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

There will be daily reading assignments, which we will then discuss critically during the class sessions. All of these will be posted in PDF format on a course Moodle. In addition, there will be two books to be read over the course of the semester. Both of these can be accessed from the ETH library or in PDF form free of charge. They are:

The Climate Casino, by William Nordhaus. Yale University Press.


Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Assessments</th>
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</thead>
<tbody>
<tr>
<td>Concepts and Theories</td>
<td>assessed</td>
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<table>
<thead>
<tr>
<th>Domain B - Method-specific Competencies</th>
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</thead>
<tbody>
<tr>
<td>Analytical Competencies</td>
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<tr>
<td>Decision-making</td>
<td>assessed</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>not assessed</td>
</tr>
<tr>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td>Negotiation</td>
<td>not assessed</td>
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<tr>
<td>Domain D - Personal Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td>Creative Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>assessed</td>
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701-1651-00L

Environmental Governance

Abstract

The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

Objective

To understand how an environmental problem may (not) become a policy and explain political processes, using basic concepts and techniques from political science.

To analyze the evolution as well as the key elements of environmental governance.

Content

Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.

Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Lecture notes

We mostly work with readings from the following books:


Prerequisites / notice

A detailed course schedule will be made available at the beginning of the semester.

During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental policy and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy)
This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

Student will be able to:

- Communicate the findings from these simulations and associated analysis in a manner that makes transparent their theoretical foundation, the level and sources of uncertainty, and ultimately their applicability to the policy problem.
- Develop and program numerical models to simulate the processes and relationships, in order to identify policy problems and the effects of policy interventions.
- Communicate the findings from these simulations and associated analysis in a manner that makes transparent their theoretical foundation, the level and sources of uncertainty, and ultimately their applicability to the policy problem.
- Develop and program numerical models to simulate the processes and relationships, in order to identify policy problems and the effects of policy interventions.

Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

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<thead>
<tr>
<th>Number</th>
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<th>Lecturers</th>
</tr>
</thead>
</table>
| 701-1453-00L | Ecological Assessment and Evaluation          | W    | 3    | 3G    | F. Knaus
| 701-1565-00L | Quantitative Policy Analysis and Modeling     | O    | 6    | 4G    | A. Patt, R. Garrett, B. Pickering, T. Tröndle

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

### Modeling and Statistical Analysis

**Prerequisites / notice**

- Domain A - Subject-specific Competencies
  - Concepts and Theories: assessed

- Domain B - Method-specific Competencies
  - Analytical Competencies: assessed
  - Decision-making: assessed
  - Media and Digital Technologies: assessed
  - Problem-solving: assessed

- Domain C - Social Competencies
  - Communication: assessed
  - Cooperation and Teamwork: assessed

- Domain D - Personal Competencies
  - Creative Thinking: assessed
  - Critical Thinking: assessed
  - Self-awareness and Self-reflection: assessed
  - Self-direction and Self-management: assessed

**Abstract**

The course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.

**Objective**

At the end of the course, the students should:

- have an understanding of agent-based modeling
- have an understanding of MATSim
- have an understanding of the process needed to set up an agent-based study
- have practical experience of using MATSim to perform practical transportation studies

**Content**

This course provides an introduction to agent-based models for transportation policy analysis. Four essential topics are covered:

1. Introduction of agent-based modeling and its comparison to the traditional state of practice modeling
2. Introduction of MATSim, an open-source agent-based model, developed at ETH Zurich and TU Berlin, and its various parts
3. Setting up an agent-based model simulation, where different statistical methods used in the process will be introduced and explained. Here the open-source eqasim framework used at ETH Zurich to set up agent-based models will be introduced
4. Conducting a transport policy study. The case study will be performed in groups and will include a paper-like report.

During the course, outside lecturers will give several lectures on using MATSim in practice (i.e., SBB).
The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to F. Schweitzer

**Prerequisites**

There are no strict prerequisites in terms of which lectures the students should have previously attended. However, knowledge of basic statistical theory is expected, and experience with at least one high-level programming language (Java, R, Python, or other) is recommended.

**Prerequisites / notice**

Additional relevant readings, primarily scientific articles, will be recommended throughout the course.

**363-0541-00L Systems Dynamics and Complexity**

**Abstract**

Implementing solutions: project management, critical path method, quality control feedback loop.

Controlling solutions: Vensim software, feedback cycles, control parameters, instabilities, chaos, oscillations and cycles, supply and demand, production functions, investment and consumption

**Objective**

A successful participant of the course is able to:
- understand why most real problems are not simple, but require solution methods that go beyond algorithmic and mathematical approaches
- apply the problem solving cycle as a systematic approach to identify problems and their solutions
- calculate project schedules according to the critical path method
- setup and run systems dynamics models by means of the Vensim software
- identify feedback cycles and reasons for unintended systems behavior
- analyse the stability of nonlinear dynamical systems and apply this to macroeconomic dynamics

**Content**

Why are problems not simple? Why do some systems behave in an unintended way? How can we model and control their dynamics? The course provides answers to these questions by using a broad range of methods encompassing systems oriented management, classical systems dynamics, nonlinear dynamics and macroeconomic modeling.

The course is structured along three main tasks:
1. Finding solutions
2. Implementing solutions
3. Controlling solutions

PART 1 introduces complexity as a system immanent property that cannot be simplified. It introduces the problem solving cycle, used in systems oriented management, as an approach to structure problems and to find solutions.

PART 2 discusses selected problems of project management when implementing solutions. Methods for identifying the critical path of subtasks in a project and for calculating the allocation of resources are provided. The role of quality control as an additional feedback loop and the consequences of small changes are discussed.

PART 3, by far the largest part of the course, provides more insight into the dynamics of existing systems. Examples come from biology (population dynamics), management (inventory modeling, technology adoption, production systems) and economics (supply and demand, investment and consumption). For systems dynamics models, the software program VENSIM is used to evaluate the dynamics. For economic models analytical approaches, also used in nonlinear dynamics and control theory, are applied. These together provide a systematic understanding of the role of feedback loops and instabilities in the dynamics of systems. Emphasis is on oscillating phenomena, such as business cycles and other life cycles.

Weekly self-study tasks are used to apply the concepts introduced in the lectures and to come to grips with the software program VENSIM. Another objective of the self-study tasks is to practice efficient communication of such concepts. These are provided as home work and two of these will be graded (see "Prerequisites").

**Lecture notes**

The lecture slides are provided as handouts - including notes and literature sources - to registered students only. All material is to be found on the Moodle platform. More details during the first lecture

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**Policy Engagement**

**Number**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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<tr>
<td>701-1551-00L</td>
<td>Sustainability Assessment</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>P. Krüttli, D. Neff</td>
</tr>
</tbody>
</table>

*Waiting list will be deleted October 1st, 2021.*

*No enrollment possible after October 1st, 2021.*

**Abstract**

The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

**Objective**

At the end of the course, students:

- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making

**Content**

The course is structured as follows:

- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

**Lecture notes**

Handouts are provided

**Literature**

Selected scientific articles and book-chapters

**Prerequisites**

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)
This course provides an in-depth analysis of the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 30 to 40 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG's from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It's a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

This course is about all that. The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

There will be daily reading assignments, which we will then discuss critically during the class sessions. All of these will be posted in PDF format on a course Moodle. In addition, there will be two books to be read over the course of the semester. Both of these can be accessed from the ETH library or in PDF form free of charge. They are:

The Climate Casino, by William Nordhaus. Yale University Press.

Literature


Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain C - Social Competencies
- Communication not assessed
- Cooperation and Teamwork not assessed
- Critical Thinking assessed

Domain D - Personal Competencies
- Creative Thinking not assessed
- Critical Thinking assessed

701-1563-00L

Objective

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 30 to 40 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

It’s a complicated set of problems, especially the first of these, known as mitigation. Fundamentally this is because means doing something that humanity has never really tried before at a planetary scale: deliberately altering the ways the we produce, convert, and consume energy, which is at the heart of modern society. Modern society – the entire anthropocene – grew up on fossil fuels, and the huge benefits they offered in terms of energy that was inexpensive, easy to transport and store, and very dense in terms of its energy content per unit mass or volume. How to manage a society of over 7 billion people, at anything like today’s living standards, without the benefits of that energy, is a question for which there is no easy answer. There are also other challenges outside of energy. How do we build houses, office buildings, and infrastructure networks without cement, a substance that releases large amounts of CO2 as it hardens? How do we reverse the pace of deforestation, particularly in developing countries? How do we eliminate the GHG emissions from agriculture: the methane from cows’ bellies and rice paddies, together with the chemicals that enter the atmosphere from the application of fertilizer?

These are all tough questions at a technical level, even tougher when you consider that governments typically need to employ indirect methods to get these things to happen. Arguably a government could simply pass a law that forbids people from using fossil fuels. But politically this is simply unrealistic, at least while so many people depend on fossil fuels in their daily lives. What is to be done? For this, one needs to turn to various ideas about how government can and should influence society. On the one hand are ideas suggesting that government ought to play a very limited role, relative to private actors, and should step in only to correct “market failures,” with interventions designed specifically around that failure. On the other hand are ideas suggesting that government (meaning all of us, working together through a democratic process) is the appropriate decision-making body for core decisions on where society can and should go. These issues come to the fore in climate policy discussions and debates.

This course is about all that. The goal is to give students a glimpse into the enormous complexity of this policy area, an understanding of some of the many debates that are currently raging (of which the debate about whether climate change is actually real is probably the least complicated or interesting). We want to give students the ability to evaluate policy arguments made by politicians, experts, and academics with a critical eye, informed by a knowledge of history, an understanding of the theoretical underpinnings, and the results of empirical testing of different strategies. A student taking this course ought to be able to step into an NGO or government agency involved in climate policy analysis or political advocacy, and immediately be able to make an informed and creative contribution. Moreover, by experiencing the depth of this policy area, students should be able to appreciate the complexity inherent in all policy areas.

There will be daily reading assignments, which we will then discuss critically during the class sessions. All of these will be posted in PDF format on a course Moodle. In addition, there will be two books to be read over the course of the semester. Both of these can be accessed from the ETH library or in PDF form free of charge. They are:

The Climate Casino, by William Nordhaus. Yale University Press.

Literature


Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories assessed
- Techniques and Technologies assessed

Domain B - Method-specific Competencies
- Analytical Competencies assessed
- Decision-making assessed
- Problem-solving assessed

Domain C - Social Competencies
- Communication not assessed
- Negotiation not assessed

Domain D - Personal Competencies
- Creative Thinking assessed
- Critical Thinking assessed

860-0012-00L

Objective

Climate Policy

This course provides an in-depth analysis of the theoretical underpinnings to different approaches to climate policy at the international and national levels, and how these different approaches have played out in practice. Students will learn how legislative frameworks have developed over the last 25 years, and also be able to appraise those frameworks critically.

Climate change is one of the defining challenges of our time, touching all aspects of the environment and of society. There is broad recognition (although with some dissent) that governments ought to do something about it: making sure that emissions of greenhouse gases (GHGs) stop within the next 30 to 40 years; helping people to adapt to the consequences of the climate change to which we have already committed ourselves; and, most controversially, perhaps taking measures to actively remove GHG’s from the atmosphere, or to alter the radiation balance of the Earth through solar engineering.

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There will be daily reading assignments, which we will then discuss critically during the class sessions. All of these will be posted in PDF format on a course Moodle. In addition, there will be two books to be read over the course of the semester. Both of these can be accessed from the ETH library or in PDF form free of charge. They are:

The Climate Casino, by William Nordhaus. Yale University Press.

Literature

### Electives

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<th>Type</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-3001-00L</td>
<td>Environmental Systems Data Science</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>L. Pellissier, J. Payne, B. Stocker</td>
</tr>
</tbody>
</table>

**Abstract**

Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

**Objective**

The students are able to:
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

**Content**

- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

**Prerequisites / notice**

- 252-0840-02L Anwendungsnahes Programmieren mit Python
- 401-0624-00L Mathematik IV: Statistik
- 401-6215-00L Using R for Data Analysis and Graphics (Part I)
- 401-6217-00L Using R for Data Analysis and Graphics (Part II)
- 701-0105-00L Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften

### Major in Forest and Landscape Management

#### Natural Science Foundations

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<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
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<tbody>
<tr>
<td>701-1613-01L</td>
<td>Advanced Landscape Research</td>
<td>W</td>
<td>5 credits</td>
<td>3G</td>
<td>J. Bolliger, M. Bürgi, U. Gimmi, M. Hunziker</td>
</tr>
</tbody>
</table>

**Abstract**

This course introduces landscapes as socially perceived, spatially and temporally dynamic entities that are shaped by natural and societal factors. Concepts and qualitative and quantitative methods to study landscapes from an ecological, societal and historical perspective are presented. In a term paper students work on a landscape-related topic of their choice.

**Objective**

Students will:
- learn about concepts and methods to quantify structural and functional connectivity in landscapes, particularly
- be introduced to the topic of landscape genetics and its benefits and (current) limitations for applied conservation
- learn about concepts and methods in scenario-based land-use change modelling
- approach an understanding of landscape as perceived environment
- learn about concepts of landscape preference and related measurement methods
- understand the role of landscape for human well-being
- be introduced into approaches of actively influencing attitudes and behavior as well as related scientific evaluation
- make use of various historical sources to study landscapes and their dynamics
- interpret landscapes as a result of ecological constraints and anthropogenic activities.

**Content**

1. Encompassing concepts and approaches
   - European Landscape Convention (ELC)
   - Ecosystem Services (ES): introduction and critical evaluation

**Thematic topics**

2. Ecological approach:
   - green infrastructure (e.g., ecological conservation areas)
   - landscape connectivity
   - landscape genetics and management applications
   - concepts of specific quantitative methods: least cost paths, resistance surfaces, Circuitscape, networks (Conefor), land-use change models, various statistical methods

3. Social-science approach:
   - principle of landscape as perceived and connoted environment
   - theories on landscape preference and place identity
   - role of landscapes for recreation, health and well-being
   - intervention approaches for influencing attitudes and related behavior
   - methods of investigating the human-landscape relationship and evaluating interventions

4. Historical approach:
   - land use history of Switzerland (agricultural history, forest and woodland history)
   - historical legacies of land use in landscapes and ecosystems
   - historic-ecological approaches and applications

5. Land change science:
   - modelling future land-use (CLUE, other scenario-based models)
   - landscape functions and services

**Lecture notes**

Handouts will be available in the course and for download

**Prerequisites / notice**

- Basic Landscape Ecology courses at Bachelor level

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<tr>
<td>701-1615-00L</td>
<td>Advanced Forest Pathology</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Prospero</td>
</tr>
</tbody>
</table>

**Abstract**

In-depth understanding of concepts, insight into current research and experience with methods of Forest Pathology based on selected pathosystems.
Objective
To know current biological and ecological research on selected diseases, to be able to comment on and understand the methods.
To understand the dynamics of selected pathosystems and disturbance processes.
To be able to diagnose tree diseases and injuries.
To know forest protection strategies and to be able to comment on them.

Content
Stress and disease, virulence and resistance, disease diagnosis and damage assessment, tree disease epidemiology, disease management, ecosystem pathology.

Systems (examples): Air pollution and trees, endophytic fungi, mycorrhiza, wood decay, conifer-rot root, Phytophthora diseases, chestnut canker and its hypoviruses, urban trees, complex diseases, emerging diseases

Lecture notes
No script, the ppt-presentations and specific articles will be made available

Literature
among others:
Prerequisites / notice
The course is composed of introductory lectures, practical work, discussions and reading. The participants should have basic knowledge in forest pathology (corresponding to the course 701-0563-00 "Wald- und Baumnarkrankheiten, see teaching book of H. Butin: Tree diseases and disorders, Oxford University Press 1995. 252 pp.").

701-1644-00L
Mountain Forest Hydrology

3G

Abstract
This course presents a process-based view of the hydrology, biogeochemistry, and geomorphology of mountain streams. Students learn how to integrate process knowledge, data, and models to understand how landscapes regulate the fluxes of water, sediment, nutrients, and pollutants in streams, and to anticipate how streams will respond to changes in land use, atmospheric deposition, and climate.

Objective
Students will have a broad understanding of the hydrological, biogeochemical, and geomorphological functioning of mountain catchments. They will practice using data and models to frame and test hypotheses about connections between streams and landscapes.

Content
Streams are integrated monitors of the health and functioning of their surrounding landscapes. Streams integrate the fluxes of water, solutes, and sediment from their contributing catchment area; thus they reflect the spatially integrated hydrological, ecophysiological, and geomorphological processes in the surrounding landscape. At a practical level, there is a significant public interest in managing forested upland landscapes to provide a reliable supply of high-quality surface water and to minimize the risk of catastrophic flooding and debris flows, but the scientific background for such management advice is still evolving.

Using a combination of lectures, field exercises, and data analysis, we explore the processes controlling the delivery of water, solutes, and sediment to streams, and how those processes are affected by changes in land cover, land use, and climate. We review the connections between process understanding and predictive modeling in these complex environmental systems. How well can we understand the processes controlling watershed-scale phenomena, and what uncertainties are unavoidable? What are the relative advantages of top-down versus bottom-up approaches? How much can "black box" analyses reveal about what is happening inside the black box? Conversely, can small-scale, micro-mechanistic approaches be successfully "scaled up" to predict whole-watershed behavior? Practical problems to be considered include the effects of land use, atmospheric deposition, and climate on streamflow, water quality, and sediment dynamics, illustrated with data from experimental watersheds in North America, Scandinavia, and Europe.

Lecture notes
Handouts will be available as they are developed.

Literature
Recommended and required reading will be specified at the first class session (with possible modifications as the semester proceeds).

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Objective
At the end of this course students will be able:

- To describe forest management and silvicultural measures for enhancing forest resilience to climate change, increased disturbances, and invasive species, and evaluate their feasibility and effectiveness in various situations;

- To concisely describe silvicultural options for the management of multifunctional forests and critically evaluate their feasibility and suitability;

- To explain the various social expectations towards forest functions and their implications for multifunctional forest management and critically analyse conflicts and synergies resulting from different forest functions;

- To carry out research on a given topic, identify relevant literature and present the results in a structured presentation and discuss the implications for forest management.

Content
The course will cover important topics for the sustainable management of multifunctional forests and present silvicultural strategies to fulfil a variety of forest ecosystem goods and services. Current and future challenges of forest management will be presented. The course is structured into the following sub-topics:

1) Global change and adaptive forest management
2) Invasive species: implications and mitigation measures
3) Introduced tree species: risks and opportunities
4) Silvicultural and forest management options the provisioning of multi-dimensional ecosystem goods and services.
5) Challenges and silvicultural strategies for wood production.
6) Integrative and segregative forest management approaches for biodiversity conservation.

Lecture notes
No class notes or text books
Lecture presentations are available for download

Literature
Literature will be provided for the group presentations.

Prerequisites / notice
Course language is English. Prerequisites: Sufficient English language skills

In addition to the lectures, students need to attend 4 all-day field excursions.
Excursion topics: Forest management and climate change, Nature-based silvicultural concepts; Soil protection and forest management; Continuous cover forestry.

Participation at all 4 full-day excursions is a prerequisite for the credits.
Excursions are held in English, German and French (some German and French knowledge is good to have).

Additional field excursions focusing on the Swiss femelschlag system, the Plenter- and other uneven-aged systems will be offered during spring term in the optional course "Selected Topics of Multifunctional Forest Management". 9 all-day field trips will provide the possibility to consolidate theoretical knowledge, to apply it to real examples in the field, to discuss with forest practitioners and further consolidate what has been taught in this course. The additional course is an important part of the overall formation on forest management and is highly recommended.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Problem-solving assessed
Project Management assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Leadership and Responsibility assessed
Self-presentation and Social Influence assessed

Domain D - Personal Competencies
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics assessed

Decision Making, Policy and Planning

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<th>Number</th>
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<tr>
<td>701-1651-001L</td>
<td>Environmental Governance</td>
<td>W</td>
<td>6 credits</td>
<td>3G</td>
<td>E. Lieberherr</td>
</tr>
</tbody>
</table>

Abstract
The course addresses environmental policies, focusing on new steering approaches, which are generally summarized as environmental governance. The course also provides students with tools to analyze environmental policy processes and assesses the key features of environmental governance by examining various practical environmental policy examples.

Objective
To understand how an environmental problem may (not) become a policy and explain political processes, using basic concepts and techniques from political science.

To analyze the evolution as well as the key elements of environmental governance.

To be able to identify the main challenges and opportunities for environmental governance and to critically discuss them with reference to various practical policy examples.

Content
Improvements in environmental quality and sustainable management of natural resources cannot be achieved through technical solutions alone. The quality of the environment and the achievement of sustainable development strongly depend on human behavior and specifically the human uses of nature. To influence human behavior, we rely on public policies and other societal rules, which aim to steer the way humans use natural resources and their effects on the environment. Such steering can take place through government intervention alone. However, this often also involves governance, which includes the interplay between governmental and non-governmental actors, the use of diverse tools such as emission standards or financial incentives to steer actors' behavior and can occur at the local, regional, national or international level.

In this course, we will address both the practical aspects of as well as the scientific debate on environmental governance. The course gives future environmental experts a strong basis to position themselves in the governance debate, which does not preclude government but rather involves a spectrum from government to governance.

Key questions that this course seeks to answer: What are the core characteristics of environmental challenges from a policy perspective? What are key elements of 'environmental governance' and how legitimate and effective are these approaches in addressing persistent environmental challenges?

Lecture notes
Lecture slides and additional course material will be provided on Moodle.
The course provides the student with the spatial tools to address societal challenges toward ensuring the sustainable use of terrestrial systems and biodiversity. The details of the schedule will be optimized based on the number of students; some blocks of the course will be offered as well to students in the second semester. We recommend that students have (a) three-years BSc education of a (technical) university; (b) successfully completed Bachelor introductory course to environmental policy (Entwicklungen nationaler Umweltpolitik (or equivalent)) and (c) familiarity with key issues in environmental science and some fundamental knowledge of one social science or humanities discipline (political science, economics, sociology, history, psychology, philosophy). We will mostly work with readings from the following books:

Prerequisites / notice
A detailed course schedule will be made available at the beginning of the semester. During the lecture we will work with Moodle. We ask that all students register themselves on this platform before the lecture.

Number of participants limited to 24.

Waiting list will be deleted September 24th, 2021.

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This course provides an overview about the applicability of stable isotopes (carbon 13C, nitrogen 15N, oxygen 18O and hydrogen 2H) to ecological research questions. Topics will focus on carbon (13C), nitrogen (15N), oxygen (18O) and hydrogen (2H) at natural isotope abundance and tracer levels. Lectures will be supplemented by advanced statistical methods (GLM, GAM, CART) and basic programming (loops, functions, advanced scripting) in the statistical environment R.

- The use of GIS functionality in R

### Content

1. **The basics:**
   - Introduction to the concept of the ecological niche, and biodiversity theories. Overview of the knowledge on expected biodiversity response to global changes and conservation planning methods.
   - Introduction to the statistical methods of Generalized Linear (GLM) and Generalized Additive models (GAM), and Classification and Regression Trees (CART). Introduction to basic GIS and programming elements in the statistical environment R.

2. **The class project:**
   - Students form groups of two, and each group solves a series of applied questions independently in R using the techniques taught in the introductory classes. The students then prepare a presentation and report of the obtained results that will be discussed during a mini-symposium. Each team chooses one of the following topics for the class project:
     - a) Linking climate change velocities to species' migration capacities
     - b) Explaining and modelling land use change in Switzerland
     - c) Explaining and modelling biodiversity changes in Switzerland
     - d) Designing biodiversity conservation strategies under global changes.

### Prerequisites

Basic knowledge in statistics (OLS regression, test statistics), and basic knowledge in geographic information science.

#### Electives

##### Natural Science Foundations

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<tbody>
<tr>
<td>701-1620-00L</td>
<td>Tree Genetics – Concepts and Applications</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>A. Rudow, P. Brang, F. Gugerli, C. Sperisen</td>
</tr>
</tbody>
</table>

**Abstract**
Tress are important elements and drivers of ecosystem processes in forests and landscapes. Tree species diversity and intraspecific genetic diversity are relevant factors for continuous adaptation, required for a sustainable maintenance of forest products and services. Sustainable forest and landscape management under climate change has to take forest genetic resources into consideration.

**Objective**
- The educational goals of the course are:
  - To know basic concepts of evolution and molecular and quantitative methods of genetics.
  - To understand the most relevant processes of gene flow, adaptation and species interactions, on the basis of ecological theories and case studies on forest tree species.
  - To know management principles and instruments for the promotion and conservation of forest resources, with a view on application in practice.

**Content**
The course provides a comprehensive overview on concepts and applications of tree genetics and complements basic knowledge of biology, dendrology, forest ecology and forest management in the frame of forest and landscape management topics. It introduces concepts of evolution and genetic methods as foundations, explains the most important processes and drivers of gene flow and adaptation, including coevolutionary aspects of associated organisms, and shows relevant topics of the management of genetic resources from reproduction to conservation and monitoring. Theories and their application into practice are illustrated on behalf of case studies on forest tree species.

**Lecture notes**
Script: modular slide script (parts by each lecturer).

**Literature**

**Prerequisites / notice**
No mandatory prerequisites. Basic knowledge of dendrology and forest ecology is advantageous and recommended.

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### Ecosystem Management

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<tr>
<td>701-1453-00L</td>
<td>Ecological Assessment and Evaluation</td>
<td>W</td>
<td>3</td>
<td>3G</td>
<td>F. Knaus</td>
</tr>
</tbody>
</table>

**Abstract**
The course provides methods and tools for ecological evaluations dealing with nature conservation or landscape planning. It covers census methods, ecological criteria, indicators, indices and critically appraises objectivity and accuracy of the available methods, tools and procedures. Birds and plants are used as main example guiding through different case studies.
Objective
Students will be able to:
1) critically consider biological data books and local, regional, and national inventories;
2) evaluate the validity of ecological criteria used in decision making processes;
3) critically appraise the handling of ecological data and criteria used in the process of evaluation;
4) perform an ecological evaluation project from the field survey up to the decision making and planning.

Lecture notes
Basic literature and references are listed on the webpage.

Literature
Basic literature and references are listed on the webpage.

Prerequisites / notice
The course structure changes between lecture parts, seminars and discussions. The didactic atmosphere is intended as working group.

Suggested prerequisites for attending this course are skills and knowledge equivalent to those taught in the following ETH courses:
- Pflanzen- und Vegetationsökologie
- Systematische Botanik
- Raum- und Regionalentwicklung
- Naturschutz und Naturschutzbiologie

701-1645-00L Forest Operations

W 3 credits 2G H. Griess, J. Schweier

Abstract
The discipline of Forest operations is constantly challenged to find solutions for unique problems. Each forest site requires specific technological approaches and machinery based on given management goals and ecological and environmental circumstances. Various terrain types and soil conditions, harvesting costs and taking care of the workforce by creating safe working conditions are some of the a

Objective
In this course, students will learn to use a wide variety of approaches grounded in the natural sciences, engineering and technology to develop solutions tailored to unique challenges from the field of forest operations.

The course is aimed at students who either plan an academic or professional career in the field of forest operations, or who will work at the interface between forest operations and the various related disciplines, such as forest ecosystem management and forestry in the wider sense.

After participating in this course students will have acquired foundational knowledge of a wide variety of core elements in the field of forest operations:
• The course will provide students with the ability to describe and differentiate site and stand conditions from an engineering perspective.
• Students will gain an overview and good working knowledge of current technology used in forest operations in Switzerland and around the world.
• Students will acquire the ability to assess the strength and weaknesses of the most commonly used equipment and analyze their suitability for a given set of environmental, economic and social factors.
• Students will be able to combine different types of technology to create an optimal harvesting system for a given task, and assess a given system for its task specific suitability.
• Participants will be able to assess the sustainability and potential short- and long-term impacts of harvesting systems under ecological, economic and social constraints.
Introduction

• Historic overview
• Scope of operation
• Site and stand characteristics

Timber harvesting
• Logging methods
• Felling methods
• Motor-Manual felling methods
  o Falling and processing
• Forest machine structure and function
• Harvester Technology
  o Felling heads
  o Carriers for felling heads
• Bunching
• Mechanical processing
• Loading equipment
• Operating techniques

Primary Transport Systems
• Ground based
  o Common features
  o Skidder
  o Forwarder
  o Loader Forwarder
• Cable yarding
  o Common features
  o Wire rope
  o Cable yarding systems
  o Operating techniques
• Aerial
  o Common features
  o Operating techniques

Winch-Assisted Harvesting Operations
• Harvesting
• Primary transport

Loading Equipment

Secondary transport
• Truck configurations
• Soil compaction and contamination
• Riparian areas

Forest Operations management
• Ergonomics
• Work Safety
• Economic Aspects
• Environmental impact assessment
• Equipment selection

Forest operations across the globe
• New Zealand
• North America
  o British Columbia, Canada
  o South-eastern U.S.A

Specialized equipment for small scale forest operations

Outlook into the future of forest operations

Literature

Prerequisites / notice

701-1544-00 Forest Access and Transportation

Decision Making, Policy and Planning

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-0468-00L</td>
<td>Participatory Modeling in Integrated Landscape</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>E. Celio, N. Salliou</td>
</tr>
</tbody>
</table>

Abstract

The lecture accompanies students into a participatory modelling process. We explore topics such as urban agriculture or climate-resilient city. Students will know participatory modelling tools as well as concepts and approaches related to it. Students elaborate the processes from questions to interactive operational models.

Objective

With this course, students ... 

... know the phases of a participatory modelling process

... are able to estimate in which case the involvement of stakeholders is necessary, hence are able to discuss advantages and disadvantages of stakeholder involvement at different levels of participation.

... get to know diverse modelling tools and are able to select the proper tool according to the context.

... are able to set-up and apply a functional model in a participatory manner on a real case study.

... get to know techniques to analyse simulations and are able to inform stakeholders in an adequate way.

... are able to discuss results together with stakeholders in a structured way.
### Taught competencies

<table>
<thead>
<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Techniques and Technologies</td>
<td>assessed</td>
</tr>
<tr>
<td>Domain B - Method-specific Competencies</td>
<td>Analytical Competencies</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Decision-making</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Media and Digital Technologies</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Problem-solving</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain C - Social Competencies</td>
<td>Communication</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Teamwork</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Customer Orientation</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Leadership and Responsibility</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-presentation and Social Influence</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Sensitivity to Diversity</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Negotiation</td>
<td>not assessed</td>
</tr>
<tr>
<td>Domain D - Personal Competencies</td>
<td>Adaptability and Flexibility</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Creative Thinking</td>
<td>assessed</td>
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<tr>
<td></td>
<td>Critical Thinking</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Integrity and Work Ethics</td>
<td>not assessed</td>
</tr>
<tr>
<td></td>
<td>Self-awareness and Self-reflection</td>
<td>assessed</td>
</tr>
<tr>
<td></td>
<td>Self-direction and Self-management</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

### Methods and Tools

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1316-00L</td>
<td>Physical Transport Processes in the Natural Environment</td>
<td>W</td>
<td>3</td>
<td>2G</td>
<td>J. W. Kirchner</td>
</tr>
<tr>
<td>Abstract</td>
<td>Fluid flows transport all manner of biologically important gases, nutrients, toxins, contaminants, spores and seeds, as well as a wide range of organisms themselves. This course explores the physics of fluids in the natural environment, with emphasis on the transport, dispersion, and mixing of solutes and entrained particles, and their implications for biological and biogeochemical processes.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Objective</td>
<td>Students will learn key concepts of fluid mechanics and how to apply them to environmental problems. Weekly exercises based on real-world data will develop core skills in analysis, interpretation, and problem-solving.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>dimensional analysis, similarity, and scaling</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>solute transport in laminar and turbulent flows</td>
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<tr>
<td></td>
<td>transport and dispersion in porous media</td>
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<tr>
<td></td>
<td>transport of sediment (and adsorbed contaminants) by air and water</td>
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<tr>
<td></td>
<td>anomalous dispersion</td>
<td></td>
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</tr>
<tr>
<td>Lecture notes</td>
<td>The course is under development. Lecture materials will be distributed as they become available.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 701-1677-00L | Quantitative Vegetation Dynamics: Models from Tree to Globe | W    | 3    | 3G    | H. Lischke, U. Hiltnner, B. Rohner |
| Abstract | This course provides hands-on experience with models of vegetation dynamics across temporal and spatial scales. The underlying principles, assets and trade-offs of the different approaches are introduced, and students work in a number of small projects with these models to gain first-hand experience. |      |      |                   |
| Objective | Students will |      |      |                   |
|          | - be able to understand, assess and evaluate the fundamental properties of dynamic systems using vegetation models as case studies |      |      |                   |
|          | - obtain an overview of dynamic modelling techniques from the individual plant to the global level |      |      |                   |
|          | - understand the basic assumptions of the various model types, which dictate the skill and limitations of the respective model |      |      |                   |
|          | - be able to work with such model types on their own |      |      |                   |
|          | - appreciate the methodological basis for impact assessments of future climate change and other environmental changes on ecosystems. |      |      |                   |
| Content  | Models of individuals |      |      |                   |
|          | - Deriving single-plant models from inventory measurements |      |      |                   |
|          | - Plant models based on 'first principles' |      |      |                   |
|          | Models at the stand scale |      |      |                   |
|          | - Simple approaches: matrix models |      |      |                   |
|          | - Competition for light and other resources as central mechanisms |      |      |                   |
|          | - Individual-based stand models: distance-dependent and distance-independent |      |      |                   |
|          | - Theoretical models |      |      |                   |
|          | Models at the landscape scale |      |      |                   |
|          | - Simple approaches: cellular automata |      |      |                   |
|          | - Dispersal and disturbances (windthrow, fire, bark beetles) as key mechanisms |      |      |                   |
|          | - Landscape models |      |      |                   |
|          | Global models |      |      |                   |
|          | - Sacrificing local detail to attain global coverage: processes and entities |      |      |                   |
|          | - Dynamic Global Vegetation Models (DGVMs) |      |      |                   |
|          | - DGVMs as components of Earth System Models |      |      |                   |
| Lecture notes | Handouts will be available in the course and for download |      |      |                   |
| Literature | Will be indicated at the beginning of the course |      |      |                   |
| Prerequisites / notice | - Basic training in modelling and systems analysis |      |      |                   |
|          | - Basic knowledge of programming, ideally in R |      |      |                   |
|          | - Good knowledge of general ecology, vegetation dynamics, and forest systems |      |      |                   |

| 701-1682-00L | Dendroecology | W    | 3    | 3G    | C. Bigler, K. Treydte, G. von Arx |
| Abstract | The course dendroecology offers theoretical and practical aspects of dendrochronology. The impact of different environmental influences on tree-ring characteristics will be shown. The students learn various methods to date tree rings and they understand how ecological and environmental processes and patterns can be reconstructed using tree rings. |      |      |                   |
The students... The students are able to,...

The course communicates a deepened understanding of the geoprocessing frameworks arcpy and covers basic language concepts of

Environmental Systems Data Science

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Weekly Credits</th>
<th>Semester Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-3001-00L</td>
<td>Environmental Systems Data Science</td>
<td>3</td>
<td>2G</td>
</tr>
</tbody>
</table>

Abstract

The students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective

The students are able to

- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content

- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Literature


Prerequisites

Basic knowledge of ArcGIS is assumed.

Lecture notes

Lecture notes, exercises and worked out solutions to them will be provided.

Literature


Waiting list will be deleted September 14th, 2021.

Number of participants limited to 30.

The lecture notes and further documents (papers, software) can be downloaded from Moodle (https://moodle-app2.let.ethz.ch) following registration for the course.

Time schedule (total of 90 hours): There will be 12 lectures with each two hours (total of 24 hours presence) as well as a field and lab day (8 hours presence). In addition, the students are expected to put 18 hours into the preparation of the lectures as well as 18 hours for the exercises. 4 hours are reserved for the lab work and 18 hours for the project.

The class language is German and English, on request English only.

Requirements:

Basics of biology, ecology and forest ecology
ECTS Type: Exchange platform between forest science and forest practitioners, geared towards Swiss stakeholders

S. Beran-Ghosh

3G

Smoothing and Nonparametric Regression with

This course is geared towards outreach and dissemination of research results to Swiss forest practitioners. The overall goal of the course is to introduce students to epidemiological thinking and methods, which are crucial for understanding environmental and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.

Hours

Title

Colloquium Forest and Landscape Management

401-0627-00L

Smoothing and Nonparametric Regression with

W 4 credits

2G S. Beran-Ghosh

Abstract

Starting with an overview of selected results from parametric inference, kernel smoothing will be introduced along with some asymptotic theory, optimal bandwidth selection, data driven algorithms and some special topics. Examples from environmental research will be used for motivation, but the methods will also be applicable elsewhere.

Objective

The students will learn about methods of kernel smoothing and application of concepts to data. The aim will be to build sufficient interest in the topic and intuition as well as the ability to implement the methods to different datasets.

Content

- Parametric estimation methods: selection of important results
  - Method of Least squares: regression & diagnostics
- Nonparametric curve estimation
  - Density estimation, Kernel regression, Local polynomials, Bandwidth selection, various theoretical results related to consistency
  - Selection of special topics (as time permits, we will discuss some of the following): rapid change points, mode estimation, partial linear models, probability and quantile curve estimation, etc.
- Applications: potential areas of applications will be discussed such as, change assessment, trend and surface estimation and others.

Lecture notes

Brief summaries or outlines of some of the lecture material will be posted at https://www.wsl.ch/en/employees/ghosh.html.

NOTE: The posted notes will tend to be just sketches whereas only the in-class lessons will contain complete information.

LOG IN: In order to have access to the posted notes, you will need the course user id & the password. These will be given out on the first day of the lectures.

Literature

- Statistical Inference, by S.D. Silvey, Chapman & Hall.
- Density Estimation, by B.W. Silverman, Chapman and Hall.
- Nonparametric Simple Regression, by J. Fox, Sage Publications.

Additional references will be given out in the lectures.

Prerequisites / notice

Prerequisites: A background in Linear Algebra, Calculus, Probability & Statistical Inference including Estimation and Testing.

Colloquium

701-1691-00L

Colloquium Forest and Landscape Management

Z 0 credits

1.5K H. Bugmann

Abstract

This course is geared towards outreach and dissemination of research results to Swiss forest practitioners.

Objective

Exchange platform between forest science and forest practitioners, geared towards Swiss stakeholders

Lecture notes

wird angegeben, so weit sinnvoll

Major in Human Health, Nutrition and Environment

Public Health

The module Public Health is compulsory for all students in the major Human Health, Nutrition and Environment.

Colloquium

701-0105-00L  Mathematik VI: Angewandte Statistik für Umweltnaturwissenschaften

401-6217-00L  Using R for Data Analysis and Graphics (Part II)

401-6215-00L  Using R for Data Analysis and Graphics (Part I)

401-0624-00L  Mathematik IV: Statistik

252-0840-02L  Anwendungsnahes Programmieren mit Python

0 credits

Applied Biostatistics

W 4 credits

3G M. Tanadini

Abstract

This course covers the main methods used in Biostatistics. It starts by revising Linear Models (Regression, Anova), then moves to Generalised Linear Models (logistic regression and methods for count data) and finally introduces more advanced topics (Linear Mixed-Effects Models and Generalised Additive Models). The course strongly focuses on applied aspects of data analysis.

Objective

After this course students:
- revised Linear Models
- revised or got introduced to Generalised Linear Models
- got introduced to Linear Mixed-Effects Models
- got introduced to Generalised Additive Models
- are able to select among these methods to solve an applied problem in Biostatistics
- can perform the data analysis using the statistical software R
- can interpret the results of such an analysis and draw valid “biological” conclusions

Content

This course is structured into three parts. The first part focuses on Linear and Generalised Linear Models. The second part introduces more advanced methodologies such as Linear Mixed-Effects Models and Generalised Additive Models. Both, part one and two will include the following topics: exploratory data analysis, model fitting, model "selection", residual diagnostics, model validation and results interpretation. Analyses will be carried out using the statistical software R. Finally, in the third part of the course students will be analysing real-world datasets to put into practice the knowledge and skills acquired during the first two parts.

Prerequisites / notice

This course is mainly geared towards students in the major Human Health, Nutrition and Environment.

Epidemiology and Prevention

W 3 credits

2V M. Puhan, R. Heusser

Abstract

The module Epidemiology and Prevention describes the process of scientific discovery from the detection of a disease and its causes, to the development and evaluation of preventive and treatment interventions and to improved population health.

Objective

The overall goal of the course is to introduce students to epidemiological thinking and methods, which are critical pillars for medical and public health research. Students will also become aware of how epidemiological facts are used in prevention, practice and politics.
The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes.

Concepts and Theories

Analytical Competencies

Domain A - Subject-specific Competencies

Domain B - Method-specific Competencies

Decision-making

Problem-solving

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Domain D - Personal Competencies

Creative Thinking

Critical Thinking

752-6151-00L

Public Health Concepts

W

3 credits

2V

R. Heusser

Objective

At the end of this module students are able:

- to interpret the results of epidemiological studies
- to critically assess scientific literature
- to know the definition, dimensions and determinants of health
- to plan public health interventions and health promotion projects
- to draw a bridge from evidence to policies and politics

Abstract

The module "public health concepts" offers an introduction to key principles of public health. Students get acquainted with the concepts and methods of epidemiology. Students also learn to use epidemiological data for prevention and health promotion purposes. Public health concepts and intervention strategies are presented, using examples from infectious and chronic diseases.

Lecture notes

Handouts are provided to students in the classroom.

Taught competencies

Domain A - Subject-specific Competencies

Concepts and Theories

Domain B - Method-specific Competencies

Analytical Competencies

Project Management

Domain C - Social Competencies

Communication

Cooperation and Teamwork

Domain D - Personal Competencies

Creative Thinking

Critical Thinking

752-2122-00L

Food and Consumer Behaviour

W

2 credits

2V

M. Siegrist, C. Hartmann

Abstract

This course focuses on food consumer behavior, consumer's decision-making processes and consumer's attitudes towards food products.

Objective

The course provides an overview about the following topics: Factors influencing consumer's food choice, food and health, attitudes towards new foods and food technologies, labeling and food policy issues.

752-5103-00L

Functional Microorganisms in Foods

W

3 credits

2G

C. Lacroix, A. Geirnaert, A. Greppi

Abstract

This integration course will discuss new applications of functional microbes in food processing and products and in the human gut. Selected topics will be used to illustrate the rapid development but also limits of basic knowledge for applications of functional microorganisms to produce food with high quality and safety, and for health benefits for consumers.

Objective

To understand the principles, roles and mechanisms of microorganisms with metabolic activities of high potential for application in traditional and functional foods, and for benefiting human health. This course will integrate basic knowledge in food microbiology, physiology, biochemistry, and technology.

Content

This course will address selected and current topics targeting functional characterization and new applications of microorganisms in food and for promoting human health. Specialists from the Laboratory of Food Biotechnology, as well as invited speakers from the industry will contribute to different topics:

- Probiotics and Prebiotics: human gut microbiota, functional foods and microbial-based products for gastrointestinal health and functionality, diet-microbiota interactions, molecular mechanisms; challenges for the production and addition of probiotics to foods.
- Protective Cultures and Antimicrobial Metabolites for enhancing food quality and safety: antifungal cultures; bacteriocin-producing cultures (bacteriocins); long path from research to industry in the development of new protective cultures.
- Legal and protection issues related to functional foods
- Industrial biotechnology of flavor and taste development
- Safety of food cultures and probiotics

Students will be required to complete a Project on a selected current topic relating to functional culture development, application and claims. Project will involve information research and critical assessment to develop an opinion, developed in an oral presentation.

Lecture notes

Copy of the power point slides from lectures will be provided.

Literature

A list of topics for group projects will be supplied, with key references for each topic.

This lecture requires strong basics in microbiology.

752-6101-00L

Dietary Etiologies of Chronic Disease

W

3 credits

2V

M. B. Zimmermann

Abstract

To have the student gain understanding of the links between the diet and the etiology and progression of chronic diseases, including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Objective

To examine and understand the protective effect of foods and food ingredients in the maintenance of health and the prevention of chronic disease, as well as the progression of complications of the chronic diseases.

Content

The course evaluates food and food ingredients in relation to primary and secondary prevention of chronic diseases including diabetes, gastrointestinal diseases, kidney disease, cardiovascular disease, arthritis and food allergies.

Lecture notes

There is no script. Powerpoint presentations will be made available on-line to students.

To be provided by the individual lecturers, at their discretion.

Prerequisites / notice

No compulsory prerequisites, but prior completion of the courses "Introduction to Nutritional Science" and "Advanced Topics in Nutritional Science" is strongly advised.

Autumn Semester 2021
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Infectious Diseases

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1341-00L</td>
<td>Water Resources and Drinking Water</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>S. Hug, M. Berg, F. Hammes, U. von Gunten</td>
</tr>
</tbody>
</table>

Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this lecture is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Prerequisites / notice
Handouts will be distributed

Literature
Will be mentioned in handouts

<table>
<thead>
<tr>
<th>Number</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1353-00L</td>
<td>Nanostructured Materials Safety</td>
<td>W</td>
<td>2 credits</td>
<td>1V</td>
<td>P. Wick</td>
</tr>
</tbody>
</table>

Abstract
Fundamentals in nanostructured material - living system interactions focusing on the main exposure routes, lung, gastrointestinal tract, skin and intravenous injection

Objective
Understanding the potential side effects of nanomaterials in a context-specific way, enabling to evaluate nanomaterial safety and provide knowledge to design safer materials

Prerequisites / notice
course "Introduction to Toxicology"

Ecological Parasitology

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1471-00L</td>
<td>Ecological Parasitology</td>
<td>W</td>
<td>3 credits</td>
<td>1V+1P</td>
<td>J. Jokela, C. Vorburger</td>
</tr>
</tbody>
</table>

Waiting list will be deleted on October 1st, 2021.

Objective
1. Identify common macro parasites in invertebrates.
2. Understand ecological and evolutionary processes in host-parasite interactions.
3. Conduct parasitological research

Content
Lectures:
1. Diversity and natural history of parasites (i.e. systematic groups and life-cycles).
2. Adaptations of parasites (e.g. evolution of life-cycles, host manipulation).
3. Ecology of host-parasite interactions (e.g. parasite communities, effects of environmental changes).
4. Ecology and evolution of parasitoids and their applications in biocontrol
5. Human macro parasites (schistosomiasis, malaria).

Practical exercises:
1. Examination of parasites in molluscs (identification and examination of host exploitation strategies).
2. Examination of parasites in amphibods (identification and examination of effects on hosts).
3. Examination of parasitoids of aphids.

Prerequisites / notice
The three practicals will take place at the 05.10.2021, the 19.10.2021 and the 09.11.2021 at Eawag Dübendorf from 08:15 - 12:00. Note that each practical takes 2 hours longer than the weekly lecture.

Evolutionary Medicine for Infectious Diseases

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1703-00L</td>
<td>Evolutionary Medicine for Infectious Diseases</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>A. Hall</td>
</tr>
</tbody>
</table>

Waiting list will be deleted October 3rd, 2021.

Objective
Students will learn to (i) identify evolutionary explanations for the origins and characteristics of infectious diseases in a range of organisms and (ii) evaluate ways of integrating evolutionary thinking into improved strategies for treating infections of humans and animals. This will incorporate principles that apply across any host-pathogen interaction, as well as system-specific mechanistic information, with particular emphasis on bacteria and viruses.
Content
We will cover several topics where evolutionary thinking is relevant to understanding or treating infectious diseases. This includes: (i) determinants of pathogen host range and virulence, (ii) dynamics of host-parasite coevolution, (iii) pathogen adaptation to evade or suppress immune responses, (iv) antimicrobial resistance, (v) evolution-proof medicine. For each topic there will be a short (<20 minutes) introductory lecture, before students independently research the primary literature and develop discussion points and questions, followed by interactive discussion in class.

Literature
The focus is on primary literature, but for some parts the following text books provide good background information:
Stearns & Medzhitov 2016 Evolutionary Medicine

Prerequisites / notice
A basic understanding of evolutionary biology, microbiology or parasitology will be advantageous but is not essential.


Abstract
This course provides a detailed understanding of
- development of T and B cells
- the dynamics of an immune response during acute and chronic infection
- mechanisms of immunopathology
- modern vaccination strategies
Key experimental results will be shown to help understanding how immunological text book knowledge has evolved.

Objective
Obtain a detailed understanding of
- the development, activation, and differentiation of different types of T cells and their effector mechanisms during immune responses,
- recognition of pathogenic microorganisms by the host cells and molecular events thereafter,
- events and signals for maturation of naive B cells to antibody producing plasma cells and memory B cells.
- optimization of B cell responses by intelligent design of new vaccines

Content
- Development and selection of CD4 and CD8 T cells, natural killer T cells (NKT) and regulatory T cells (Treg)
- NK T cells and responses to lipid antigens
- Differentiation, characterization, and function of CD4 T cell subsets such as Th1, Th2, and Th17
- Overview of cytokines and their effector function
- Co-stimulation (signals 1-3)
- Dendritic cells
- Evolution of the 'Danger' concept
- Cells expressing Pattern Recognition Receptors and their downstream signals
- T cell function and dysfunction in acute and chronic viral infections

Literature
Documents of the lectures are available for download at: https://moodle-app2.let.ethz.ch/course/view.php?id=2581&notitifyeditingon=1

752-4009-00L Molecular Biology of Foodborne Pathogens W 3 credits 2V M. Loessner, M. Schmelcher, M. Schuppler, E. Wetter Slack

Abstract
The course offers detailed information on selected foodborne pathogens and toxin producing organisms; the focus lies on relevant molecular biological aspects of pathogenicity and virulence, as well as on the occurrence and survival of these organisms in foods.

Objective
Detailed and current status of research and insights into the molecular basis of foodborne diseases, with focus on interactions of the microorganism or the toxins they produce with the human system. Understanding the relationship between specific types of food and the associated pathogens and microbial risks. Another focus lies on the currently available methods and techniques useful for the various purposes, i.e., detection, differentiation (typing), and antimicrobial agents.

Content
- Molecular biology of infectious foodborne pathogens (Listeria, Vibrio, E. coli, Campylobacter, etc) and toxin-producing organisms (Bacillus, Clostridium, Staphylococcus). How and under which conditions will toxins and virulence factors be produced, and how do they work? How is the interaction between the human host and the microbial pathogen? What are the roles of food and the environment? What can be done to interfere with the potential risks? Which methods are best suited for what approach? Last, but not least, the role of bacteriophages in microbial pathogenicity will be highlighted, in addition to various applications of bacteriophage intervention for both diagnostics and antimicrobial intervention.

Lecture notes
Electronic copies of the presentation slides (PDF) and additional material will be made available for download to registered students.

Prerequisites / notice
Prerequisites are given in the first lecture

Term Paper and Seminar
The compulsory course 701-1701-00L Human Health, Nutrition and Environment: Term Paper is offered in the autumn semester only.

Number Title Type ECTS Hours Lecturers

Abstract
Writing of a review paper of scientific quality on a topic in the domain of Human Health, Nutrition and Environment based on critical evaluation of scientific literature.

Objective
- Acquisition of knowledge in the field of the review paper
- Assessment of original literature as well as synthesis and analysis of the findings
- Practising of academic writing in English
- Giving an oral presentation with discussion on the topic of the review paper

Content
Topics are offered in the domains of the major 'Human Health, Nutrition and Environment' covering 'Public Health', 'Infectious Diseases', 'Nutrition and Health' and 'Environment and Health'.

Lecture notes
Guidelines will be handed out in the beginning.

Electives

Number Title Type ECTS Hours Lecturers
701-3001-00L Environmental Systems Data Science W 3 credits 2G L. Pellissier, J. Payne, B. Stocker
Abstract

Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective

The students are able to
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content

- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Prerequisites / Notice

252-0940-02L Anwendungsnahe Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umweltwissenschaften

Minors

Minor in Sustainable Energy Use

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0967-00L</td>
<td>Project Development in Renewable Energies</td>
<td>W</td>
<td>2 credits</td>
<td>2G</td>
<td>R. Rechsteiner, A. Appenzeller</td>
</tr>
</tbody>
</table>

Abstract

Realization of projects in the field of renewable energies, analysis of legal framework conditions and risks. The students learn basics of renewable energy project realization from acknowledged experts active in the field. They identify different tasks of various investor types. They develop sample projects in practice within groups.

Objective

You become acquainted with the regulative, juridical and economic requirements of project development in renewable energies in the field of wind power, solar power and hydro power. You learn to launch and judge projects by exercises in groups. You recognize chances and risks of renewable energy projects.

Content

Business models for renewable energy projects
- Introduction of market trends, market structure, technical trends and regulation in Switzerland and in the EU internal energy market
- Necessary frame conditions for profitable projects
- Project development samples and exercises in wind power, hydro power, photovoltaics
- Due diligence and country assessment

Lecture Notes

PPT presentation will be distributed (in German)
- Exact Program in German below

Literature

RENEW21 Renewables GLOBAL STATUS REPORT
http://www.ren21.net/status-of-renewables/
- Mit einer grünen Anlage schwarze Zahlen schreiben http://www.rechsteiner-basel.ch/uploads/media/Mit_einer_gruenen_Anlage_schwarze_Zahlen_schreiben.pdf
- UNEP: Global Trends in Renewable Energy Investments
- IEA PVPS: TRENDS 2014 IN PHOTOVOLTAIC APPLICATIONS
http://www.iea-pvps.org/
- Bundesamt für Energie: Perspektiven für die Grosswasserkraft in der Schweiz
http://www.news.admin.ch/NSSSubscriber/message/attachments/33285.pdf
- Windenergie-Report Deutschland http://windmonitor.iwes.fraunhofer.de/windmonitor_de/5_Veroeffentlichungen/1_windenergierapport/

Prerequisites / Notice

For group exercise and presentation reasons the number of participants is limited at 30 students. For exercises students build learning and presentational groups.

701-1346-00L Carbon Mitigation

Abstract

Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective

The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content

From the large number of carbon sequestration/mitigation options, a few options will be selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Lecture Notes

None

Literature

Will be identified based on the chosen topic.
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

Energy and Climate Systems I

Abstract
The first semester of the annual course focuses on physical principles, component and systems for the efficient and sustainable heating, cooling and ventilation of buildings on different scales and the interaction of technical systems with architectural and urban design.

Objective
The lecture series focuses on the physical principles and technical components of relevant systems for an efficient and sustainable climatisation and energy supply of buildings. A special focus is on the interrelation of supply systems and architectural design and construction. Learning and practicing methods of quantifying demand and supply allows identifying parameters relevant for design.

Content
1. Introduction and overview
2. Heating and cooling systems in buildings
3. Ventilation

Lecture notes
The slides of the lecture serve as lecture notes and are available as download.

Literature
A list of relevant literature is available at the chair.

Power Market I - Portfolio and Risk Management

Abstract
Portfolio and risk management in the electrical power business, Pan-European power market and trading, futures and forward contracts, hedging, options and derivatives, performance indicators for the risk management, modelling of physical assets, cross-border trading, ancillary services, balancing power market, Swiss market model.

Objective

Content
1. Pan-European power market and trading
   1.1. Power trading
   1.2. Development of the European power markets
   1.3. Energy economics
   1.4. Spot and OTC trading
   1.5. European energy exchange EEX
2. Market model
   2.1. Market place and organisation
   2.2. Balance groups / balancing energy
   2.3. Ancillary services
   2.4. Market for ancillary services
   2.5. Cross-border trading
   2.6. Capacity auctions
3. Portfolio and Risk management
   3.1. Portfolio management 1 (introduction)
   3.2. Forward and futures contracts
   3.3. Risk management 1 (m2m, VaR, hpcf, volatility, cVaR)
   3.4. Risk management 2 (PaR)
   3.5. Contract valuation (HPFC)
   3.6. Portfolio management 2
   2.8. Risk Management 3 (enterprise wide)
4. Energy & Finance I
   4.1. Options 1 basics
   4.2. Options 2 hedging with options
   4.3. Introduction to derivatives (swaps, cap, floor, collar)
   4.4. Financial modelling of physical assets
   4.5. Trading and hydro power
   4.6. Incentive regulation

Lecture notes
Handouts of the lecture

Prerequisites / notice
1 excursion per semester, 2 case studies, guest speakers for specific topics.
Course Moodle: https://moodle-app2.let.ethz.ch/enrol/index.php?id=11636

Minor in Global Change and Sustainability

This minor will only be offered in the academic year 21/22. As of the academic year 22/23, the minor can no longer be chosen. The course units offered in the minor can still be taken as electives.

Number Title Type ECTS Hours Lecturers
701-0019-00L Readings in Environmental Thinking W 3 credits 2S J. Ghazoul

This course introduces students to foundational texts that led to the emergence of the environment as a subject of scientific importance, and shaped its relevance to society. Above all, the course seeks to give confidence and raise enthusiasm among students to read more widely around the broad subject of environmental sciences and management both during the course and beyond.

Objective
The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.
The course will be run as a book reading club. The first session will provide a short introduction as to how to explore a particular text (that is not a scientific paper) to identify the key points for discussion.

Thereafter, in each week a text (typically a chapter from a book or a paper) considered to be seminal or foundational will be assigned by a course lecturer. The lecturer will introduce the selected text with a brief background of the historical and cultural context in which it was written, with some additional biographical information about the author. He/she will also briefly explain the justification for selecting the particular text.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:
- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.

The specific texts selected for discussion will vary, but examples include:
- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

### 701-1551-00L Sustainability Assessment

**Number of participants limited to 35.**

**Waiting list will be deleted October 1st, 2021.**

**Abstract**

The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

**Objective**

At the end of the course, students:
- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making

The course is structured as follows:
- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

**Content**

Handouts are provided

**Literature**

Selected scientific articles and book-chapters

**Prerequisites / notice**

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

### 551-0209-00L Sustainable Plant Systems (Seminar)

**Abstract**

Participants will be able to discuss and understand sustainability in the context of plant science research. A special focus will be on research on agro-ecological systems and farming system research.

**Objective**

Participants will be able to:
1. Review issues of sustainability in the context of plant science research and literature on sustainable agriculture and the food system.
2. Analyze and interact on several case studies in agro-ecology and the food system.
3. Use SDGs in your case study as a target and assessment system for sustainability in agriculture and in the food system.
Content
Future society has to feed nine billion people, therefore agriculture but also food, waste and resource management has to go hand in hand in the use of less resources. We will discuss current plant science research in the context of sustainability. Focus of the seminar will be on:

1. Research on agro-ecological systems and farming system research. Can we transform our agricultural practices and move behind existing paradigms to develop innovative and sustainable agriculture production systems? Where does current research indicate on directions for transformation of current practice and how can we assess and analyse them?
2. The Sustainable Development Goals that should guide the current contributions of plant sciences: What research and innovation are necessary to contribute to the SDGs? How can we assess their possible contribution in the near future?
3. Sustainable food systems: How could local food systems be build and scaled? In this topic, our focus is on giving insight in policy strategies and local sustainability efforts to give the group of participants an opportunity to understand sustainability in a real societal context.

The course will be organized with two workshops (half days, 14:00 - 18:00) and an intensive, well-structured self-study/group work phase in between the workshops. Online learning material in provided on for example:

1. Biotic interactions
2. Nutrient management
3. Plant breeding
4. Global change

Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107

T. Bernauer

This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Abstraction
This seminar focuses on the technical, economic, and political challenges of dealing with water allocation and pollution problems in large international river systems. It examines ways and means through which such challenges are addressed, and when and why international efforts in this respect succeed or fail.

Objective
Based on lectures and discussion of scientific papers and reports, students acquire basic knowledge on contentious issues in managing international water resources, on the determinants of cooperation and conflict over international water issues, and on ways and means of mitigating conflict and promoting cooperation. Students will then, in small teams coached by the instructors, carry out research on a case of their choice (i.e. an international river basin where riparian countries are trying to find solutions to water allocation and/or water quality problems associated with a large dam project). They will write a brief paper and present their findings towards the end of the semester.

Methods
This seminar will be organized with two workshops (half days, 14:00 - 18:00) and an intensive, well-structured self-study/group work phase in between the workshops. Online learning material in provided on for example:

1. Biotic interactions
2. Nutrient management
3. Plant breeding
4. Global change

Access to the learning platform: https://lms.uzh.ch/auth/RepositoryEntry/3604873218/CourseNode/83441794245107

T. Bernauer

This course focuses on the conditions under which such efforts and the respective public policies are effective.

Objective
The objectives of this course are to (1) gain an overview of relevant questions in the area of international environmental politics from a social sciences viewpoint; (2) learn how to identify interesting/innovative questions concerning this policy area and how to answer them in a methodologically sophisticated way; (3) gain an overview of important global and regional environmental problems and how they could be solved.

In-depth case study.
This course deals with how and why international problem solving efforts (cooperation) in environmental politics emerge, and under what circumstances such efforts are effective. Based on theories of international political economy and theories of government regulation various examples of international environmental politics are discussed: the management of international water resources, political responses to global warming, the protection of the stratospheric ozone layer, the reduction of long-range transboundary air pollution, protection of biodiversity, how to deal with plastic waste, the prevention of pollution of the oceans, etc.

The course is open to all ETH students. Participation does not require previous coursework in the social sciences.

After passing an end-of-semester test (requirement: grade 4.0 or higher) students will receive 3 ECTS credit points. The workload is around 90 hours (meetings, reading assignments, preparation of test).

Visiting students (e.g., from the University of Zurich) are subject to the same conditions. Registration of visiting students in the web-based system of ETH is compulsory.

This course will take place fully online. Course units have three components:

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

1. A pre-recorded lecture by Prof. Bernauer, available via Moodle, for all course units
2. Reading assignments, available via Moodle, for a few selected course units
3. Online meetings (via Zoom) for all course units on Mondays at 16:30 – 18:00, where we discuss your questions concerning the lecture and reading assignments and focus in greater depth on a particular facet of the respective course unit, on occasion with a guest (to be announced a few weeks ahead of the respective course unit).

You must watch the lecture and complete the reading assignment for the respective unit ahead of the online meeting. The online meeting will be recorded and made available via Moodle.

To facilitate your planning, the course is organized in terms of weekly units.

### Minor in Transdisciplinarity for Sustainable Development

This minor will only be offered in the academic year 21/22. As of the academic year 22/23, the minor can no longer be chosen. The course units offered in the minor can still be taken as electives.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1551-00L</td>
<td>Sustainability Assessment</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>P. Krüti, D. Nef</td>
</tr>
</tbody>
</table>

Waiting list will be deleted October 1st, 2021.

No enrollment possible after October 1st, 2021.

**Abstract**

The course teaches concepts and methodologies of sustainability assessment. A special focus is given to the social dimension and to social justice as a guiding principle of sustainability. The format of the course is seminar-like, interactive.

**Objective**

At the end of the course, students:

- know core concepts of sustainable development, main features of social justice in the context of sustainability, a selection of methodologies for the assessment of sustainable development
- have a deepened understanding of the challenges of trade-offs between the different dimensions of sustainable development and their respective impacts on individual and societal decision-making

**Content**

The course is structured as follows:

- overview of rationale, objectives, concepts and origins of sustainable development (approx. 15%)
- overview of the concept of social justice as guiding principle of the social dimension of sustainability (approx. 20%)
- analysis of a selection of concepts and methodologies to assess sustainable development in a variety of contexts (approx. 65%)

**Lecture notes**

Handouts are provided

**Literature**

Selected scientific articles and book-chapters

**Prerequisites / notice**

Students of this course may also be interested in the course transdisciplinary case study (tdCS) in the Spring semester (701-1502-00L)

### Minor in Life Cycle Assessment

This minor will only be offered in the academic year 21/22. As of the academic year 22/23, the minor can no longer be chosen. The course units offered in the minor can still be taken as electives.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-0577-00L</td>
<td>An Introduction to Sustainable Development in the</td>
<td>W</td>
<td>3 credits</td>
<td>2G</td>
<td>G. Habert, D. Kaushal</td>
</tr>
</tbody>
</table>
Abstract
In 2015, the UN Conference in Paris shaped future world objectives to tackle climate change.
What does it mean for the built environment?
This course provides an introduction to the notion of sustainable development when applied to our built environment.

Objective
At the end of the semester, the students have an understanding of the term of sustainable development, its history, the current political and scientific discourses and its relevance for our built environment.

In order to address current challenges of climate change mitigation and resource depletion, students will learn a holistic approach of sustainable development. Ecological, economical and social constraints will be presented and students will learn about methods for argumentation and tools for assessment (i.e. life cycle assessment).

For this purpose an overview of sustainable development is presented with an introduction to the history of sustainability and its today definition as well as the role of cities, urbanisation and material resources (i.e. energy, construction material) in social economic and environmetal aspects.

The course aims to promote an integral view and understanding of sustainability and describing different spheres (social/cultural, ecological, economical, and institutional) that influence our built environment.

Students will acquire critical knowledge and understand the role of involved stakeholders, their motivations and constraints, learn how to evaluate challenges, identify deficits and define strategies to promote a more sustainable construction.

After the course students should be able to define the relevance of specific local, regional or territorial aspects to achieve coherent and applicable solutions toward sustainable development.

The course offers an environmental, socio-economic and socio-technical perspective focussing on buildings, cities and their transition to resilience with sustainable development. Students will learn on theory and application of current scientific pathways towards sustainable development.

Content
The following topics give an overview of the themes that are to be worked on during the lecture.

- Overview on the history and emergence of sustainable development
- Overview on the current understanding and definition of sustainable development

Methods
- Method 1: Life cycle assessment (planning, construction, operation/use, deconstruction)
- Method 2: Life Cycle Costing
- Method 3: Labels and certification

Main issues:
- Operation energy at building, urban and national scale
- Mobility and density questions
- Embodied energy for developing and developed world
- Synthesis: Transition to sustainable development

Lecture notes
All relevant information will be online available before the lectures. For each lecture slides of the lecture will be provided.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.

<table>
<thead>
<tr>
<th>101-0608-00L</th>
<th>Design-Integrated Life Cycle Assessment</th>
<th>W</th>
<th>3 credits</th>
<th>2G</th>
<th>G. Habert</th>
</tr>
</thead>
</table>

Abstract
Currently, Life Cycle Assessment (LCA) is applied as an ex-post design evaluation of buildings, but rarely used to improve the building during the design process.

The aim of this course is to apply LCA during the design of buildings by means of a digital, parametric tool. The necessary fundamentals of the LCA method will be taught following a lecture on demands approach.

Objective
The course will follow two main objectives and a third optional objective, depending on the design projects the students' choose. At the end of the course, the students will:
1. Know the methodology of LCA
2. Be able to apply LCA in the design process to assess and improve the environmental performance of their projects
3. Be able to use the parametric LCA tool and link it to additional performance assessment tools for a holistic optimisation

Content
The course will be structured into two parts, each making up about half of the semester.

Part I: Exercises with lectures on demand
The first six individual courses will follow the "lectures on demand" approach. Small "hands-on" exercises focusing on one specific aspect will be given out and the necessary background knowledge will be provided in the form of short input lectures when questions arise. The following topics will be discussed during the first part:
1) LCA basic introduction
2) System boundaries, functional unit, end of life
3) Carbon budget and LCA benchmarks
4) BIM-LCA, available calculation tools and databases
5) Integrated analysis of environmental and cost assessment
6) Bio-based carbon storage

Part II: Project-based learning
In the second part, the students have an understanding of the basic LCA principles and practice the tools in a design project. For the design task, the students will bring their own project and work on improving it. The projects can be chosen depending on the students background and range from buildings to infrastructure projects. Intermediate presentations will ensure the continuous work and make sure all groups are on the same level and learn from each other. During this part, the following hands-on tutorials will be given:
1) Introduction to Rhinoceros 6 and 7
2) Introduction to grasshopper
3) Integrated assessment tools (ladybug tools)
4) Introduction to in-house grasshopper plugin for LCA analysis

Lecture notes
As the course follows a lecture on demand approach, the lecture slides will be provided after each course.

Literature
A list of the basic literature will be offered on a specific online platform, that could be used by all students attending the lectures.
Advanced Environmental Assessments

Master students in Environmental Engineering choosing module Ecological Systems Design are not allowed to enrol 102-0317-00 Advanced Environmental Assessments (3KP) as already included in 102-0307-01 Advanced Environmental, Social and Economic Assessments (5KP).

Abstract
This course deepens students’ knowledge of the environmental assessment methodologies and their various applications.

Objective
This course has the aim of deepening students’ knowledge of the environmental assessment methodologies and their various applications. In particular, students completing the course should have the
- Ability to judge the scientific quality and reliability of environmental assessment studies, the appropriateness of inventory data and modelling, and the adequacy of life cycle impact assessment models and factors
- Knowledge about the current state of the scientific discussion and new research developments
- Ability to properly plan, conduct and interpret environmental assessment studies
- Knowledge of how to use LCA as a decision support tool for companies, public authorities, and consumers

Content
- Inventory developments, transparency, data quality, data completeness, and data exchange formats
- Allocation (multiooutput processes and recycling)
- Hybrid LCA methods.
- Consequential and marginal analysis
- Recent development in impact assessment
- Spatial differentiation in Life Cycle Assessment
- Workplace and indoor exposure in Risk and Life Cycle Assessment
- Uncertainty analysis
- Subjectivity in environmental assessments
- Multicriteria analysis
- Case Studies

Lecture notes
No script. Lecture slides and literature will be made available on Moodle.

Literature
No script. Lecture slides and literature will be made available on Moodle.

Prerequisites / notice
Basic knowledge of environmental assessment tools is a prerequisite for this class. Students that have not done classwork in this topic before are required to read an appropriate textbook before or at the beginning of this course (e.g. Jolliet, O et al. 2016: Environmental Life Cycle Assessment. CRC Press, Boca Raton - London - New York. ISBN 978-1-4398-8766-0 (Chapters 2-5.2)).

102-0317-03L
Advanced Environmental Assessment (Computer Lab I)
W
1 credit
1U
S. Pfister

Abstract
Different tools and software used for environmental assessments, such as LCA are introduced. The students will have hands-on exercises in the computer rooms and will gain basic knowledge on how to apply the software and other resources in practice.

Objective
Become acquainted with various software programs for environmental assessment including Life Cycle Assessment, Environmental Risk Assessment, Probabilistic Modeling, Material Flow Analysis.

102-0317-04L
Advanced Environmental Assessment (Computer Lab II)
W
2 credits
2P
S. Pfister

Abstract
Technical systems are investigated in projects, based on the software and tools introduced in the course 102-0317-03L Advanced Env. Assessment (Computer Lab I). The projects are created around a complete but simplified LCA study, where the students will learn how to answer a given question with target oriented methodologies using various software programs and data sources for env. assessment.

Objective
Become acquainted with utilizing various software programs for environmental assessment to perform a Life Cycle Assessment and learn how to address the challenges when analyzing a complex system with available data and software limitations.

Prerequisites / notice
Prerequisite is enrolment of 102-0317-00 Advanced Environmental Assessments and of 102-0317-03 Advanced Environmental Assessments (Computer Lab I) in parallel or in advance (both courses in HS).

Minor in Biogeochemistry

This minor will only be offered in the academic year 21/22. As of the academic year 22/23, the minor can no longer be chosen. The course units offered in the minor can still be taken as electives.

701-1313-00L
Isotopes and Biomarkers in Biogeochemistry
W
3 credits
2G
C. Schubert, R. Kipfer

Abstract
The course introduces the scientific concepts and typical applications of tracers in biogeochemistry. The course covers stable and radioactive isotopes, geochemical tracers and biomarkers and their application in biogeochemical processes as well as regional and global cycles. The course provides essential theoretical background for the lab course “Isotopic and Organic Tracers Laboratory”.

Objective
The course aims at understanding the fractionation of stable isotopes in biogeochemical processes. Students learn to know the origin and decay modes of relevant radiogenic isotopes. They discover the spectrum of possible geochemical tracers and biomarkers, their potential and limitations and get familiar with important applications

Content
- Geogenic and cosmogenic radionuclides (sources, decay chains);
- Stable isotopes in biogeochemistry (natural abundance, fractionation);
- Geochemical tracers for processes such as erosion, productivity, redox fronts; biomarkers for specific microbial processes.

Lecture notes
Handouts will be provided for every chapter

Literature
A list of relevant books and papers will be provided

Prerequisites / notice
Students should have a basic knowledge of biogeochemical processes (BSc course on Biogeochemical processes in aquatic systems or equivalent)

701-1315-00L
Biogeochemistry of Trace Elements
W
3 credits
2G
A. Voegelin, S. Bouchet, L. Winkel

Abstract
The course addresses the biogeochemical classification and behavior of trace elements, including key processes driving the cycling of important trace elements in aquatic and terrestrial environments and the coupling of abiotic and biotic transformation processes of trace elements. Examples of the role of trace elements in natural or engineered systems will be presented and discussed in the course.
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this course is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Lecture notes
Handouts will be distributed

Literature
Will be mentioned in handouts

701-1341-00L Water Resources and Drinking Water W 3 credits 2G S. Hug, M. Berg, F. Hammes, U. von Gunten

Abstract
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. Natural processes, anthropogenic pollution, legislation of groundwater and surface water and of drinking water as well as water treatment will be discussed for industrialized and developing countries.

Objective
The goal of this course is to give an overview over the whole path of drinking water from the source to the tap and understand the involved physical, chemical and biological processes which determine the drinking water quality.

Content
The course covers qualitative (chemistry and microbiology) and quantitative aspects of drinking water from the resource to the tap. The various water resources, particularly groundwater and surface water, are discussed as part of the natural water cycle influenced by anthropogenic activities such as agriculture, industry, urban water systems. Furthermore legislation related to water resources and drinking water will be discussed. The lecture is focused on industrialized countries, but also addresses global water issues and problems in the developing world. Finally unit processes for drinking water treatment (filtration, adsorption, oxidation, disinfection etc.) will be presented and discussed.

Lecture notes
Handouts will be distributed

Literature
Will be mentioned in handouts

701-1346-00L Carbon Mitigation W 3 credits 2G N. Gruber

Number of participants limited to 100
Priority is given to the target groups: Bachelor and Master Environmental Sciences and PhD Environmental Sciences until September 21st, 2021. Waiting list will be deleted October 1st, 2021.

Abstract
Future climate change can only kept within reasonable bounds when CO2 emissions are drastically reduced. In this course, we will discuss a portfolio of options involving the alteration of natural carbon sinks and carbon sequestration. The course includes introductory lectures, presentations from guest speakers from industry and the public sector, and final presentations by the students.

Objective
The goal of this course is to investigate, as a group, a particular set of carbon mitigation/sequestration options and to evaluate their potential, their cost, and their consequences.

Content
From the large number of options, particularly selected and then investigated in detail by the students. The results of this research will then be presented to the other students, the involved faculty, and discussed in detail by the whole group.

Lecture notes
None

Literature
Will be identified based on the chosen topic.

Prerequisites / notice
Exam: No final exam. Pass/No-Pass is assigned based on the quality of the presentation and ensuing discussion.

Minor in Physical Glaciology

Number Title Type ECTS Hours Lecturers
101-0289-00L Applied Glaciology W 4 credits 2G D. Farinotti, A. Bauder, M. Werder

Abstract
The course transmits fundamental knowledge for treating applied glaciological problems. Topics include climate-glacier interactions, glacier ice flow, glacier hydrology, ice avalanches, and lake ice.

Objective
The objectives of the courses are to:
- learn about fundamental glaciological processes, including glacier mass balance, ice dynamics, and glacier-related hazards;
- apply the above knowledge to some case studies inspired by contract-works performed at ETH's Glaciology section;
- generate the own computer code to solve the above case studies, and interpret the results;
- understand, both in class and in the field, the practical relevance of glaciology, with a focus on the Swiss applications.

Content
The course will develop along the following outline:
- How glaciology became a scientific discipline
- Glaciology and hydropower
- Glacier mechanics and ice flow
- Gravitational glacier instabilities
- Glacier hydrology and glacier lake outbursts
- Lake ice and ice bearing capacity
- Field excursion to Jungfraujoch
- Discussion of the exercises performed during the semester

Lecture notes
Digital lecture handouts will be distributed prior to each class.

Literature
Links to relevant literature will be provided during the classes.

Prerequisites / notice
Completed BSc studies. Basic knowledge in computer scripting in any language (e.g. Python, R, Julia, Matlab, IDL, ...) will be advantageous for solving the exercises. The exercises will be performed in groups. A minimal level of fitness is required for the field excursion.
Adaptability and Flexibility

Risks to life and human assets result when settlement areas and infrastructure overlap regions where natural hazard processes occur. This course utilizes case studies to teach how a future natural hazards-specialist should analyze, assess and manage risks.

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651-1581-00L Seminar in Glaciology
W 3 credits 2S A. Bauder

Abstract
Introduction to classic and modern literature of research in Glaciology. Active participation is expected and participants are mentored by PhD students of Glaciology.

Objective
In-depth knowledge of selected topics of research in Glaciology. Introduction to different types of scientific presentation. Improve ability of discussion of scientific topics.

Content
Selected topics of scientific research in Glaciology

Lecture notes
Copies/pdf of scientific papers will be distributed during the course

Prerequisites / notice
Active participation is expected with presence at the sessions. Only a limited number of participants can be accepted. One of the following courses should be taken as preparation:
- 651-3561-00L Kryosphäre
- 101-0289-00L Applied Glaciology
- 651-4101-00L Physics of Glaciers

651-4077-00L Quantification and Modeling of the Cryosphere: Dynamic Processes (University of Zurich)
W 3 credits 1V University lecturers

Abstract
Overview of the most important earth surface processes and landforms in cold regions (regions with glaciers and intense frost) with emphasis on high-mountain aspects. Discussion of present research challenges.

Objective
Knowledge of the most prominent climate-related geomorphological processes and phenomena in high-mountain regions, understanding of primary research challenges.

Content
Erosion and sedimentation by glaciers as a function of topography, englacial temperature, sediment balance, sliding and melt water runoff. Processes and landforms in regions of seasonal and perennial frost (frost weathering, rock falls, debris cones/talus, solifluction, permafrost creep/rock glaciers, debris flows).

Lecture notes
Glacial and periglacial geomorphodynamics in high-mountain regions. Ca. 100 pages.

Literature
References in script

Prerequisites / notice
Basic knowledge about geomorphology and glaciers/permafrost from corresponding courses at ETH/UZH or from the related lecture notes.

651-4101-00L Physics of Glaciers
W 3 credits 3G M. Lüthi, F. T. Walter, M. Werder

Abstract
Understanding glaciers and ice sheets with simple physical concepts. Topics include the reaction of glaciers to the climate, flow of glacier ice, temperature in glaciers and ice sheets, glacier hydrology, glacier seismology, basal motion and calving glaciers. A special focus is the current development of the ice sheets of Greenland and Antarctica.

Objective
After the course the students are able understand and interpret measurements of ice flow, subglacial water pressure and ice temperature. They will have an understanding of glaciology-related physical concepts sufficient to understand most of the contemporary literature on the topic. The students will be well equipped to work on glacier-related problems by numerical modeling, remote sensing, and field work.

Content
The dynamics of glaciers and polar ice sheets is the key requisite to understand their history and their future evolution. We will take a closer look at ice deformation, basal motion, heat flow and glacier hydraulics. The specific dynamics of tide water and calving glaciers is investigated, as is the reaction of glaciers to changes in mass balance (and therefore climate).

Lecture notes
http://people.ee.ethz.ch/~luethim/teaching.html

Literature
A list of relevant literature is available on the class web site.

Prerequisites / notice
High school mathematics and physics knowledge required.

Minor in Catchment Management and Natural Hazards

Number Title Type ECTS Hours Lecturers
701-0565-00L Fundamentals of Natural Hazards Management W 3 credits 3G V. Griess, B. Krummenacher, S. Löw

Abstract
Does not take place this semester.

Risks to life and human assets result when settlement areas and infrastructure overlap regions where natural hazard processes occur. This course utilizes case studies to teach how a future natural hazards-specialist should analyze, assess and manage risks.
Concepts will be explained step-by-step through a set of case studies, and applied in lab by the students. The following principal steps are used when coping with natural hazard-risks. At each step, students will learn and apply the following skills:

Risk analysis - What can happen?
- Characterize the processes and environmental measures that lead to a natural hazard and integrate modeling results of these processes.
- Identify threats to human life and assets exposed to natural hazards and estimate possible drawbacks or damages.
Risk assessment - What are the acceptable levels of risk?
- Apply principles to determine acceptable risks to human life and assets in order to identify locations which should receive added protection.
- Explain causes for conflicts between risk perception and risk analysis.
Risk management - What steps should be taken to manage risks?
- Explain how various hazard mitigation approaches reduce risk.
- Describe hazard scenarios as a base for adequate dimensioning of control measures.
- Identify the best alternative from a set of thinkable measures based on an evaluation scheme.
- Explain the principles of risk-governance.

Die Vorlesung besteht aus folgenden Blöcken:

1) Einführung ins Vorgehenskonzept (1W)
2) Risikoanalyse (6W + Exkursion) mit:
   - Systemabgrenzung
   - Gefahrenbeurteilung
   - Expositions- und Folgenanalyse
3) Risikobewertung (2W)
4) Risikomanagement (2W + Exkursion)
5) Abschlussbesprechung (1W)

101-1250-00L

Management of Hillslope and Channel Processes

D. Rickenmann

Objective

Ziel
To recognise and understand channel and hillslope processes and their interactions. To learn about methods of hazard analysis and of technical and bioengineering protection measures and their assessment. Determination of critical loads and design of protective structures. Assessment of spatial and future developments with and without protective measures.

Content

Inhalt

Lecture notes

see “Literatur”

Literature


Prerequisites / notice

Besonderes
Requirements:
- Essentials of Construction Analysis
- Hydraulics
- Geology and Petrography
- Soil Physics
- Soil Mechanics and Geotechnics

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Media and Digital Technologies
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-direction and Self-management

102-0293-00L

Hydrology

P. Burlando

Objective

Know the main features of engineering hydrology. Apply methods to estimate hydrological variables for dimensioning hydraulic structures and managing water resources.
The hydrological cycle: global water resources, water balance, space and time scales of hydrological processes.

Precipitation: mechanisms of precipitation formation, precipitation measurements, variability of precipitation in space and time, precipitation regimes, point/basin precipitation, isohyetal method, Thiessen polygons, storm rainfall, design hyetograph.

Interception: measurement and estimation.

Evaporation and evapotranspiration: processes, measurement and estimation, potential and actual evapotranspiration, energy balance method, empirical methods.

Infiltration: measurement, Horton’s equation, empirical and conceptual models, phi-index and percentage method, SCS-CN method.

Surface runoff and subsurface flow: Hortonian and Dunnian surface runoff, streamflow measurement, streamflow regimes, annual hydrograph, flood hydrograph analysis – baseflow separation, flow duration curve.

Basin characteristics: morphology, topographic and phreatic divide, hypsometric curve, slope, drainage density.

Rainfall-runoff models (R-R): rationale, linear model of rainfall-runoff transformation, concept of the instantaneous unit hydrograph (IUH), linear reservoir, Nash model.

Flood estimation methods: flood frequency analysis, deterministic methods, probabilistic methods (e.g. statistical regionalisation, indirect R-R methods for flood estimation, rational method).

Erosion and sediment transport: watershed scale erosion, soil erosion by water, estimation of surface erosion, sediment transport.

Snow (and ice) hydrology: snow characteristic variables and measurements, estimation of snowmelt processes by the energy budget equation and conceptual melt models (temperature index method and degree-day method), snowmelt runoff.

**Prerequisites / notice**

Knowledge of statistics is a prerequisite. The required theoretical background, which is needed for understanding part of the lectures and performing part of the assignments, may be summarised as follows:

Elementary data processing: hydrological measurements and data, data visualisation (graphical representation and numerical parameters).

Frequency analysis: hydrological data as random variables, return period, frequency factor, probability paper, probability distribution fitting, parametric and non-parametric tests, parameter estimation.

**Lecture notes**

The lecture notes as well as the lecture presentations and handouts may be downloaded from the website of the Chair of Hydrology and Water Resources Management.

**Lecture notes**

Written course documentation available under "Kursunterlagen".

**Literature**


**Lecture notes**

Written course documentation available under "Kursunterlagen".

**Literature**


**Minor in Forest Engineering and Wood Products**

To successfully complete this minor, KPAs must be earned for the two required courses:

- 701-1645-00 Forest Operations (autumn semester) and
- 701-1544-00 Forest Access and Transportation (spring semester)
### Number: 701-1645-00L  
**Title:** Forest Operations  
**Type:** O  
**ECTS:** 3  
**Hours:** 2G  
**Lecturers:** H. Griess, J. Schweier

#### Abstract
The discipline of Forest operations is constantly challenged to find solutions for unique problems. Each forest site requires specific technological approaches and machinery based on given management goals and ecological and environmental circumstances. Various terrain types and soil conditions, harvesting costs and taking care of the workforce by creating safe working conditions are some of the aspects to be considered. In this course, students will learn to use a wide variety of approaches grounded in the natural sciences, engineering and technology to develop solutions tailored to unique challenges from the field of forest operations.

#### Objective
In this course, students will learn to use a wide variety of approaches grounded in the natural sciences, engineering and technology to develop solutions tailored to unique challenges from the field of forest operations. The course is aimed at students who either plan an academic or professional career in the field of forest operations, or who will work at the interface between forest operations and the various related disciplines, such as forest ecosystem management and forestry in the wider sense.

After participating in this course students will have acquired foundational knowledge of a wide variety of core elements in the field of forest operations:
- The course will provide students with the ability to describe and differentiate site and stand conditions from an engineering perspective.
- Students will gain an overview and good working knowledge of current technology used in forest operations in Switzerland and around the world.
- Students will acquire the ability to assess the strength and weaknesses of the most commonly used equipment and analyze their suitability for a given set of environmental, economic and social factors.
- Students will be able to combine different types of technology to create an optimal harvesting system for a given task, and assess a given system for its task specific suitability.
- Participants will be able to assess the sustainability and potential short- and long-term impacts of harvesting systems under ecological, economic and social constraints.

#### Content

**Introduction**
- Historic overview
- Scope of operation
- Site and stand characteristics

**Timber harvesting**
- Logging methods
- Felling methods
- Motor-Manual felling methods
  - Falling and processing
- Forest machine structure and function
  - Harvester Technology
    - Felling heads
      - Carriers for felling heads
    - Bunching
    - Mechanical processing
    - Loading equipment
    - Operating techniques

**Primary Transport Systems**
- Ground based
  - Common features
  - Skidder
  - Forwarder
  - Loader Forwarder
- Cable yarding
  - Common features
  - Wire rope
  - Cable yarding systems
  - Operating techniques
- Aerial
  - Common features
  - Operating techniques

**Winch-Assisted Harvesting Operations**
- Harvesting
- Primary transport

**Loading Equipment**

**Secondary transport**
- Truck configurations
- Soil compaction and contamination
- Riparian areas

**Forest Operations management**
- Ergonomics
- Work Safety
- Economic Aspects
- Environmental impact assessment
- Equipment selection

**Forest operations across the globe**
- New Zealand
- North America
  - British Columbia, Canada
  - South-eastern U.S.A

**Specialized equipment for small scale forest operations**

**Outlook into the future of forest operations**

**Literature**
Published on Moodle

**Prerequisites / notice**
701-1544-00 Forest Access and Transportation
I. Burgert

Objective
Learning target is a basic understanding of the anatomy of wood and the related impact of endogenous and exogenous factors. The students can learn how to distinguish common central European wood species at the macroscopic and microscopic level. A deeper insight will be given by wood identification exercises for softwood species. Further, the students will gain insight into the relationships between tree growth and wood properties with a specific focus on the wood function in the living tree.

Content
In an introduction to wood anatomy, the general structural features of softwoods and hardwoods will be explained and factors of diversity and variability will be discussed. A specific focus is laid on common central European tree species with relevance in the wood sector, which will be studied in macro- and microstructural investigations. In the following, relationships between wood structure, properties and function in the living tree will be in the focus of the lectures. Topics covered are water transport, trends in wood anatomy within trees, environmental impact on wood anatomy, wood defects and their causes, tools to study wood properties over time, secondary changes in wood, and tree biomechanics.

101-0637-20L  Fundamentals of Wood Elaboration and Woodmachining
Abstract
The course Wood processing conveys knowledge on technological properties of wood and wood-based materials as well as on industrial processes for the fabrication of a vast variety of wood products and covers new developments in the field of digital technologies.

Objective
Learning target is a fundamental understanding of the dominating wood machining processes, which are applied to fabricate common wood products. Students will be introduced to the economic relevance of the renewable resource wood and are trained in its technological properties. The students will learn to identify the relationships between wood species and their properties as well as the suitable wood machining processes to fabricate targeted wood products. Finally, the digital transformation process, which will affect all sectors of the wood industry with impact on the entire value chain and business models will be covered. It will be illustrated how production processes will become more flexible, efficient and less resource demanding.

Content
The general introduction shows the economic relevance of the wood resource in a global, European and Swiss context and reflects aspects of sustainability in wood production and certification. In terms of bulk wood products a specific focus in laid on sawn timber production and drying processes. With regard to wood veneer production, steaming, veneer cutting and assembly to veneer lumber products are presented. Further the common technologies for the production of particle boards and fibre boards as well as paper will be discussed. In the following, the topics are related to wood gluing and wood protection as well as potentials and limitations in the application of wood and wood-based products. In a further part, the lecture deals with the most important digital technologies, e.g. Internet of Things, artificial intelligence and their impact on the wood industry on the basis of illustrative examples. At the end of the lecture an excursion to a Swiss wood manufacturer is planned, in order to facilitate practical experience.

Minor in Soil-Plant Relations and Land Use
This minor will only be offered in the academic year 21/22. As of the academic year 22/23, the minor can no longer be chosen. The course units offered in the minor can still be taken as electives.

Number | Title | Type | ECTS | Hours | Lecturers
--- | --- | --- | --- | --- | ---
103-0317-00L  Introduction to Spatial Development and Transformation
Abstract
The course deals with important theoretical, material and methodical foundations for action and decision-making of spatial relevance. This course discusses central tasks and possible solutions for current and future challenges of spatial development in Switzerland and Europe.

Objective
Spatial development deals with the development, formation and arrangement of our environment. In order to be able to mediate between the different demands, interests and projects of multiple actors, a forward-looking, action-oriented and robust planning is necessary. It is committed - in the sense of a sustainable spatial development - to the economical handling of resources, in particular of the non-replicable resource soil.

Content
The lecture introduces necessary basic knowledge and is based on the following main topics:
- Planning approaches and The (political) steering of spatial development
- Interplay of formal and informal processes and processes across different scales of spatial development
- Methods of action-oriented planning in situations of insecurity
- Integrated space and infrastructure development
- Different types of participation in spatial development

Lecture notes
By taking up the lecture, the students are able to recognize cross-scale, complex tasks of spatial development and transformation and to use their theoretical, methodical and professional knowledge to clarify them.

Taught competencies
For further information and the documents for the lecture can be found on the homepage of IRL/STL

Domain A - Subject-specific Competencies
Concepts and Theories - assessed
Techniques and Technologies - assessed

Domain B - Method-specific Competencies
Analytical Competencies - assessed
Decision-making - assessed
Problem-solving - assessed
Project Management - not assessed

Domain C - Social Competencies
Cooperation and Teamwork - not assessed

Domain D - Personal Competencies
Creative Thinking - assessed
Critical Thinking - assessed
Self-direction and Self-management - not assessed

751-3405-00L  Chemical Nature of Nutrients and their Availability to Plants: The Case of Phosphorus
Abstract
The course Chemical Nature of Nutrients and their Availability to Plants: The Case of Phosphorus conveys basic knowledge on the biogeochemistry of essential nutrients, focusing on phosphorus. It includes the chemical forms of phosphorus, its availability in soils and its cycling in terrestrial ecosystems.

Objective
Learning target is to understand the chemical nature of phosphorus and its availability to plants. Students will gain insight into the importance of phosphorus as an essential nutrient for plant growth and development.

Content
The course discusses aspects of phosphorus cycling, including its role in soils, its availability to plants, and its environmental significance. It also covers strategies for improving phosphorus availability in agricultural systems.

Number of participants limited to 15.
Documents will be distributed during the lecture.

Lecture notes

Prerequisites / notice

751-5101-00L

Biogeochemistry and Sustainable Management

W
2 credits

G

W. Eugster, V. Klaus

701-1695-00L

Soil Science Seminar

Z
0 credits

S

R. Kretzschmar, A. Carminati,
S. Dötterl, E. Frossard, M. Hartmann

701-1343-00L

Soil-Plant Water Relations

W
3 credits

V

A. Carminati

751-5201-10L

Tropical Cropping Systems, Soils and Livelihoods

W
2 credits

G

J. Six, K. Benabderrazik

Tropical Cropping Systems, Soils and Livelihoods

This course has been restructured due to Covid-19 restrictions, part I (2 CP) takes place in Autumn 2021, part II (3 CP) in Spring 2022, with an excursion/fieldwork. For more information, please contact the lecturer: kenza.benabderrazik@usys.ethz.ch

Abstract

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

Objective

The students will be able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants are discussed, with particular attention on the effect of drought on root water uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed.

Abstract

This course focuses on the interactions between ecology, biogeochemistry and management of agro- and forest ecosystems, thus, coupled human-environmental systems. Students learn how human impacts on ecosystems via management or global change are mainly driven by effects on biogeochemical cycles and thus ecosystem functioning, but also about feedback mechanisms of terrestrial ecosystems.

Objective

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.

Abstract

This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, Resilience to Soil physics.
Objective
Part 1
(1) Overview of the major land use systems in Tropical agroecosystems in several contexts Africa
(2) Interdisciplinary analysis of agricultural production systems
(3) Knowledge on methods to assess Food and energy security in tropical agroecosystems

Part 2
(4) Hands-on training on the use of field methods, diagnostic tools and survey methods.
(5) Gain practical knowledge on how to assess Food and Energy Security
(6) Collaboration in international students and stakeholders

Content
Part 1 (Fall semester 2021)
This course guides students in analyzing and comprehending tropical agroecosystems. Students gain theoretical knowledge of field methods, diagnostic tools for tropical soils and agroecosystems. Various experts will present their projects and perspectives on various subjects from Food security, resilience to soil physics or agricultural economics. Students will engage in readings, discussions and exchanges on the specificities of tropical agriculture.

Part 2 (Spring 2022)
On the second module, students gain practical knowledge on field - An integral part of the course is the two-week field project in a Tropical region, meeting several stakeholders of the agricultural and food systems and conducting various assessments related to Food and Energy Security.

Prerequisites / notice
Students can only join Part 2 if Part 1 was taken and validated first.
A selection of 20 students for the Part 2 will be done on the basis of several elements. We would require the students enrolled to the class to send a short cover letter (1-page max.) by September 28th 2021, justifying your motivation to enroll to this class.

Taught competencies
Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain C - Social Competencies
Communication assessed
Cooperation and Teamwork assessed
Self-presentation and Social Influence assessed
Sensitivity to Diversity assessed

Domain D - Personal Competencies
Adaptability and Flexibility assessed
Critical Thinking assessed
Self-awareness and Self-reflection assessed
Self-direction and Self-management assessed

Minor in Agricultural Plant Production and Environment

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<tr>
<td>701-1343-00L</td>
<td>Soil-Plant Water Relations</td>
<td>W</td>
<td>3</td>
<td>2V</td>
<td>A. Carminati</td>
</tr>
</tbody>
</table>

Abstract
Water limitation is a primary constraint on plant growth and terrestrial fluxes worldwide. In this course, the principles of water flow in soil and plants are discussed, with particular attention on the effect of drought on root uptake, transpiration and plant growth. Strategies of plants to tolerate drought are discussed.

Objective
The students are able to: explain and compare systematically the drivers of water stress to plants; to solve the equations of water flow in soil and plants and to calculate plant water status for varying pedoclimatic conditions and plant traits; to critically review and present one research question in soil-plant water relations; to openly debate on the current trends in soil and plant water research.

Content
24.09: Introduction.
01.10: Soil water relations; Principles of soil water retention and soil water flow; Soil hydraulic properties.
08.10: Root water uptake; soil hydraulic constraints on transpiration
15.10: Rhizosphere processes and properties; root-soil contact; root hairs; mycorrhiza; rhizodeposition.
22.10: Water flow in roots and xylem; root anatomy, architecture and plasticity; cavitation.
29.10: Transpiration; Vapor Pressure Deficit; Photosynthesis; Stomatal regulation.
05.11: Soil-plant-atmospheric continuum; Below- and above-ground feedbacks; Soil and atmospheric drivers of transpiration losses.
12.11: Modelling Soil-Plant Water Relations (Concept)
19.11: Modelling Soil-Plant Water Relations (Implementation)
26.11: Plant response to drought and consequences for agriculture and forests. Open questions and introduction to seminar topics.
03.12: Group work in the class
10.12: Seminar (presentation of papers)
17.12: Seminar (presentation of papers)
24.12: Seminar (presentation of papers)

Literature
Lecture notes; selection of articles

Prerequisites / notice
Vadose Zone Hydrology/Environmental Soil Physics (recommended but not required)

751-3700-00L | Plant Ecophysiology | W    | 2    | 2V    | M. Gharun, M. Lehmann, A. Walter

Abstract
The general theme of this course is the effect of environmental factors (such as light, temperature, relative humidity, CO2 concentrations, etc.) on plant physiology: water uptake and transport, transpiration, CO2 gas exchange of plants (photosynthesis, respiration), growth and C allocation, yield and production, stress physiology. Lab and field measurements are also included.

Objective
The students will understand the impact of environmental factors on plant physiology and will have hands-on experiences with equipment used in plant ecophysiology.

Content
This course provides an in-depth analysis of the major challenges and advancements in plant physiological research. The students will critically assess the latest research and methodologies in the field.

Lecture notes
Handouts stehen online.

Literature

Prerequisites / notice
This course is based on fundamental understanding of plant physiology and is recommended for students with a strong background in plant biology.

751-4003-01L | Current Topics in Grassland Sciences (HS) | W    | 2    | 2S   | A. K. Gilgen

Abstract
Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as Ph.D. and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.
Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.

During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomical features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.

Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops. Accordingly, this knowledge will be imparted during the course and will be required to understand the mechanisms of integrated weed control strategies.

The course will address a wide range of agricultural and food system challenges (e.g. food security, climate change, soil degradation, etc.) in both temperate and tropical contexts, from building food system resilience through innovative measures, to addressing soil fertility and GHG emissions. A wide variety of case studies will be presented, covering different scales (e.g. value-chains, farm and soil management). The class is complemented by a role-playing exercise on food system transformation. Students will gain an overview on institutions and actors’ roles in the field of sustainable agricultural development. Throughout the exercise, students will learn to cooperate through a teamwork exercise and understand what is the role of each stakeholders in the food system in order to support a sustainable transformation.

The class is complemented by a role-playing exercise on food system transformation. Students will gain an overview on institutions and actors’ roles in the field of sustainable agricultural development. Throughout the exercise, students will learn to cooperate through a teamwork exercise and understand what is the role of each stakeholders in the food system in order to support a sustainable transformation.

Objective
Students will be able to understand and evaluate experimental design and data interpretation of on-going studies, be able to critically analyze published research results, practice to present and discuss results in the public, and gain a broad knowledge of recent research and current topics in agro- and forest ecosystem sciences.

Content
Research results in agro- and forest ecosystem sciences will be presented by experienced researchers as well as Ph.D. and graduate students. Citation classics as well as recent research results will be discussed. Topics will range from plant ecophysiology, biodiversity and biogeochemistry to management aspects in agro- and forest ecosystems.

Lecture notes
none

Prerequisites / notice
Prerequisites: Basic knowledge of plant ecophysiology, terrestrial ecology and management aspects in agro- and forest ecosystems. Course will be taught in English.

751-4104-00L

Objective
Alternative Crops

Abstract
Few crops dominate the crop rotations worldwide. Following the goal of an increased agricultural biodiversity, species such as buckwheat but also medicinal plants might become more important in future. The biology, physiology, stress tolerance and central aspects of the value-added chain of the above-mentioned and of other alternative crops will be depicted.

Objective
During this course, students learn to assess the potential of different minor or alternative crops compared to the dominant major crops based on their biological and agronomical features. Each student will assess and present a specific alternative crop of his or her choice based on information from scientific articles and Wikipedia. Wikipedia-entries will be generated.

751-4704-00L

Objective
Weed Science

Abstract
Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops.

Objective
At the end of the course the students are qualified to develop sustainable solutions for weed problems in agricultural and natural habitats.

Content
Modern weed management comprises competent knowledge of weed biology, weed ecology, population dynamics, crop-weed-interactions and different measures to control weeds. Weeds are understood to be rather part of a habitat or a cropping system than just unwanted plants in crops. Accordingly, this knowledge will be imparted during the course and will be required to understand the mechanisms of integrated weed control strategies.

751-5003-00L

Sustainable Agroecosystems II

Objective
(1) Systematically analyse and discuss case studies from ongoing agroecological and food system research.

(2) Learn and experiment on methods for field and laboratory investigations in agroecology.

(3) Engage with positive and empowering frameworks that motivate critical reflection and action on the types of transformative responses needed to adapt and thrive within agricultural and food systems.

(4) Reflect critically on agricultural and food system transformation tools and methods from the perspective a food system stakeholder.

(5) Identify and describe institutions in the context of sustainable agricultural development (for Bachelor and Master thesis and internships).

Content
This class conveys current topics and methods of agroecological and food systems research through selected case studies from ongoing research of the Sustainable Agroecosystems group. Students will be encouraged to develop critical thinking competencies, through individual and group work, on major agricultural and food system challenges and paths towards agricultural and food system transformation.

Literature


Number
Title
Type
ECTS
Hours
Lecturers

363-0537-00L

Resource and Environmental Economics

W
3 credits
2G
L. Bretschger

Relationship between economy and environment, market failures, external effects and public goods, contingent valuation, internalisation of externalities, economics of non-renewable resources, economics of renewable resources, environmental cost-benefit analysis, sustainability economics, and international resource and environmental problems.

A successful completion of the course will enable a thorough understanding of the basic questions and methods of resource and environmental economics and the ability to solve typical problems using appropriate tools consisting of concise verbal explanations, diagrams or mathematical expressions. Concrete goals are first of all the acquisition of knowledge about the main questions of resource and environmental economics and about the foundation of the theory with different normative concepts in terms of efficiency and fairness. Secondly, students should be able to deal with environmental externalities and internalisation through appropriate policies or private negotiations, including knowledge of the available policy instruments and their relative strengths and weaknesses. Thirdly, the course will allow for in-depth economic analysis of renewable and non-renewable resources, investigating the role of stock constraints, regeneration functions, market power, property rights and the impact of technology. A fourth objective is to successfully use the well-known tool of cost-benefit analysis for environmental policy problems, which requires knowledge of the benefits of an improved natural environment. The last two objectives of the course are the acquisition of sufficient knowledge about the economics of sustainability and the application of environmental economic theory and policy at international level, e.g. to the problem of climate change.

Content
The course covers all the interactions between the economy and the natural environment. It introduces and explains basic welfare concepts and market failure; external effects, public goods, and environmental policy; the measurement of externalities and contingent valuation; the economics of non-renewable resources, renewable resources, cost-benefit-analysis, sustainability concepts; international aspects of resource and environmental problems; selected examples and case studies. After a general introduction to resource and environmental economics, highlighting its importance and the main issues, the course explains the normative basis, utilitarianism, and fairness according to different principles. Pollution externalities are a deep core topic of the lecture. We explain the governmental internalisation of externalities as well as the private internalisation of externalities (Coase theorem). Furthermore, the issues of free rider problems and public goods, efficient levels of pollution, tax vs. permits, and command and control instruments add to a thorough analysis of environmental policy. Turning to resource supply, the lecture first looks at empirical data on non-renewable natural resources and then develops the optimal price development (Hotelling-rule). It deals with the effects of explorations, new technologies, and market power.

When treating the renewable resources, we look at biological growth functions, optimal harvesting of renewable resources, and the overuse of open-access resources. A next topic is cost-benefit analysis with the environment, requiring measuring environmental benefits and measuring costs. In the chapter on sustainability, the course covers concepts of sustainability, conflicts with optimality, and indicators of sustainability. In a final chapter, we consider international environmental problems and in particular climate change and climate policy.

Literature

751-0423-00L Risk Analysis and Risk Management in Agriculture W 3 credits 2G R. Finger
Abstract
Agricultural production is exposed to various risks and risk management is indispensable. This course introduces modern concepts on farmers’ decision making under risk and risk management. We present innovative insights, empirical example from European agriculture.
Objective
- to develop a better understanding of decision making under uncertainty and risk;
- gain hands-on experience in risk analysis and management using R
- to gain experience in different approaches to analyze risky decisions;
- to develop an understanding for different sources of risk in agricultural production;
- to understand the crucial role of subjective perceptions and preferences for risk management decisions;
- to get an overview on risk management in the agricultural sector, with a particular focus on insurance solutions
Content
- Quantification and measurement of risk
- Risk preferences, Expected Utility Theory, Cumulative Prospect Theory
- Production and input use decisions under risk
- Portfolio Theory and Farm Diversification
- Forwards, Futures, Crop Insurance
- Weather Index Insurance and Satellite Imagery
- Empirical Applications using R
Lecture notes
Handouts will be distributed in the lecture and available on the moodle.

751-0903-00L Microeconomics of the Agriculture and Food Sector W 3 credits 2V S. Wimmer
Abstract
In dieser Vorlesung sollen Mikroökonomische Zusammenhänge am Fallbeispiel des Agrar- und Ernährungssektors vermittelt werden. Ziel ist das Verständnis theorietischer mikroökonomischer Methoden und deren Anwendbarkeit auf den Ernährungssektor
Objective
Zunächst sollen ökonomische Charakteristika des Lebensmittelsektors herausgearbeitet und gegenüber anderen Industriesektoren differenziert werden. Daraufhin sollen theoretische mikroökonomische Modelle und Indikatoren erlernt werden. Insbesondere soll deren Anwendung auf reale Fälle der Schweizer und EU Lebensmittelindustrie vermittelt werden.
Content
- Der EU Lebensmittelsektor
- Preiselastizitäten von Angebot und Nachfrage im Ernährungssektor (Marktmacht, Lancaster Modell)
- Gewinnmaximierung
- Wettbewerbsangebot
- Monopol/ Monopolistischer Wettbewerb/ Monopson
- Oligopol (Stackelberg, Cournot, Bertrand)
- Preisdifferenzierung
- Kartelle
- Dominante Firma
Prerequisites / notice
Empfohlene Vorkenntnisse:
- Grundkenntnisse der Ökonomie/Agrarökonomie
- Vorlesung Einführung in die Mikroökonomie

751-1311-00L Introduction to Agricultural Management W 2 credits 2V R. Finger
Abstract
Vermittlung von betriebswirtschaftlichen Grundlagenwissen und Analyse- und Planungsinstrumenten mit Anwendung auf Unternehmen der Agrar- und Ernährungswirtschaft
Objective
Teilnehmer des Kurses sollen am Ende der Vorlesung i) grundlegende Unternehmensentscheide strukturieren und analysieren können, ii) verschiedene Analyse- und Planungsinstrumente auf Fragestellungen der Produktionsplanung, Investition und Finanzierung an Beispielen anwenden können, iii) verschiedene Werkzeuge zur unternehmerischen Entscheidungsunterstützung anwenden können und iv) die Spezifika von Unternehmen in der Agrar- und Ernährungswirtschaft kennen.
Content
Die Vorlesung geht auf folgende Inhalte, mit spezifischen Anwendungen im Agrar- und Ernährungssektor ein:
- Grundlagen und Ziele unternehmerischen Entscheids
den
- Kosten und Leistungsrechnung
- Produktionstheorie
- Produktionsprogrammplanung
- Investitionsplanung und Finanzierung
- Entscheidungen unter Unsicherheit und Risikomanagement
Lecture notes
Vorlesungsunterlagen werden im Laufe des Semesters zur Verfügung gestellt

751-1573-00L Dynamic Simulation in Agricultural and Regional Economics W 2 credits 2V B. Kopainsky
Abstract
In this class, students learn the basics of system dynamics and its application to agricultural and regional economic questions. In the second half of the class, students develop their own simulation model, with which they evaluate potential interventions for improving the economic as well as the ecological sustainability of food systems.
The main part of this lecture will examine constellations where hierarchies, markets or cooperation have been observed and described in the agricultural sector. On a more aggregated level, different agricultural systems will be evaluated in terms of main socioeconomic parameters like social capital or perceptions.

### Objective
Students should be able to describe the dynamics of hierarchies, markets and cooperation in an agricultural context.

### Content
- Introduction to Sociology
- Introduction to Socioeconomics
- Agricultural Administration: Path dependencies and efficiency issues
- Power in the Chain
- The farming family
- Occupational Choices
- Consumption Choices
- Locational Choices
- Common Resource Management in Alpine Farming
- Agricultural Cooperatives
- Societal perceptions of agriculture
- Perceptions of farming from within
- Varieties of agricultural systems and policies

### Literature
- see script

### Prerequisites
Basic economic knowledge is expected.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Lecture notes</th>
<th>Literature</th>
<th>Prerequisites / notice</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Students learn the basic theory and practice of dynamic simulation</td>
<td>slides (will be provided during the class)</td>
<td>articles and papers (will be provided during the class)</td>
<td></td>
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</tbody>
</table>

### Electives

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-0019-00L</td>
<td>Readings in Environmental Thinking</td>
<td>W</td>
<td>3 credits</td>
<td>2S</td>
<td>J. Ghazouli</td>
</tr>
</tbody>
</table>

### Other

The course will provide students with opportunities to read, discuss, evaluate and interpret key texts that have shaped the environmental movement and, more specifically, the environmental sciences. Students will gain familiarity with the foundational texts, but also understand the historical context within which their academic and future professional work is based. More directly, the course will encourage debate and discussion of each text that is studied, from both the original context as well as the modern context. In so doing students will be forced to consider and justify the current societal relevance of their work.

The students will read the text, with two to four students (depending on class size) being assigned to present it at the next session. Presentation of the text requires the students to prepare by, for example:
- identifying the key points made within the text
- identifying issues of particular personal interest and resonance
- considering the impact of the text at the time of publication, and its importance now
- evaluating the text from the perspective of our current societal and environmental position

Such preparation would be supported by a mid-week tutorial discussion (about 1 hour) with the assigning lecturer.

These students will then present the text (for about 15 minutes) to the rest of the class during the scheduled class session, with the lecturer facilitating the subsequent class discussion (about 45 minutes). Towards the end of the session the presenting students will summarise the emerging points (5 minutes) and the lecturer will finish with a brief discussion of how valuable and interesting the text was (10 minutes). In the remaining 15 minutes the next text will be presented by the assigning lecturer for the following week.
The specific texts selected for discussion will vary, but examples include:

- Leopold (1949) A Sand County Almanach
- Carson (1962) Silent Spring
- Jared Diamond (2005) Collapse

Discussions might also encompass films or other forms of media and communication about nature.

701-3001-00L Environmental Systems Data Science  W  3 credits  2G  L. Pellissier, J. Payne, B. Stocker

Abstract
Students are introduced to a typical data science workflow using various examples from environmental systems. They learn common methods and key aspects for each step through practical application. The course enables students to plan their own data science project in their specialization and to acquire more domain-specific methods independently or in further courses.

Objective
The students are able to:
- frame a data science problem and build a hypothesis
- describe the steps of a typical data science project workflow
- conduct selected steps of a workflow on specifically prepared datasets, with a focus on choosing, fitting and evaluating appropriate algorithms and models
- critically think about the limits and implications of a method
- visualise data and results throughout the workflow
- access online resources to keep up with the latest data science methodology and deepen their understanding

Content
- The data science workflow
- Access and handle (large) datasets
- Prepare and clean data
- Analysis: data exploratory steps
- Analysis: machine learning and computational methods
- Evaluate results and analyse uncertainty
- Visualisation and communication

Prerequisites / notice
252-0840-02L Anwendungsnahe Programmieren mit Python
401-0624-00L Mathematik IV: Statistik
401-6215-00L Using R for Data Analysis and Graphics (Part I)
401-6217-00L Using R for Data Analysis and Graphics (Part II)
701-0105-00L Mathematik VI: Angewandte Statistik für Umwelt- und Naturwissenschaften

363-1065-00L Design Thinking: Human-Centred Solutions to Real World Challenges  W  5 credits  5G  S. Brusoni

Abstract
The goal of this course is to engage students in a multidisciplinary collaboration to tackle real world problems. Following a design thinking approach, students will work in teams to solve a set of design challenges that are organized as a one-week, a three-week, and a final six-week project in collaboration with an external project partner.

Objective
During the course, students will learn about different design thinking methods and tools. This will enable them to:
- Generate deep insights through the systematic observation and interaction of key stakeholders (empathy).
- Engage in collaborative ideation with a multidisciplinary team.
- Rapidly prototype and iteratively test ideas and concepts by using various materials and techniques.

Content
The purpose of this course is to equip the students with methods and tools to tackle a broad range of problems. Following a Design Thinking approach, the students will learn how to observe and interact with key stakeholders in order to develop an in-depth understanding of what is truly important and emotionally meaningful to the people at the center of a problem. Based on these insights, the students ideate on possible solutions and immediately validate them through quick iterations of prototyping and testing using different tools and materials. The students will work in multidisciplinary teams on a set of challenges that are organized as a one-week, a three-week, and a final six-week project with an external project partner. In this course, the students learn about the different Design Thinking methods and tools that are needed to generate deep insights, to engage in collaborative ideation, rapid prototyping and iterative testing.

Design Thinking is a deeply human process that taps into the creative abilities we all have, but that get often overlooked by more conventional problem solving practices. It relies on our ability to be intuitive, to recognize patterns, to construct ideas that are emotionally meaningful as well as functional, and to express ourselves through means beyond words or symbols. Design Thinking provides an integrated way by incorporating tools, processes and techniques from design, engineering, the humanities and social sciences to identify, define and address diverse challenges. This integration leads to a highly productive collaboration between different disciplines.

For more information and the application visit: http://sparklabs.ch/

Prerequisites / notice
Open mind, ability to manage uncertainty and to work with students from various background. Class attendance and active participation is crucial as much of the learning occurs through the work in teams during class. Therefore, attendance is obligatory for every session. Please also note that the group work outside class is an essential element of this course, so that students must expect an above-average workload.

Please note that the class is designed for full-time MSc students. Interested MAS students need to send an email to Linda Armbruster to learn about the requirements of the class.

Course Catalogue of ETH Zurich

Professional Internship

Number  Title  Type  ECTS  Hours  Lecturers
701-1001-00L Professional Internship  O  30 credits  30  A. Funk

Only for Environmental Sciences MSc.
Completion and enrollment for the course «Professional Internship» is only possible after admission requirements and all additional requirements are fulfilled.

Registration and recognition of professional internship via https://www.lehrbetrieb.ethz.ch/praxis
No registration in myStudies required. For more
### Master’s Thesis

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>701-1002-00L</td>
<td>Master's Thesis</td>
<td>O</td>
<td>30 credits</td>
<td>64D</td>
<td>Lecturers</td>
</tr>
</tbody>
</table>

Only students who fulfill the following criteria are allowed to begin with their Master's thesis:

- The signed request for the Bachelor's Degree Certificate has been submitted or processed.
- At least 32 CP of coursework related to the major have been acquired.
- All additional requirements (as stated in the admissions decision), including any assessment repetitions, are fulfilled.

Additional information is posted on the following webpage: [https://www.usys.ethz.ch/en/studies/environmental-sciences/master/internship.html](https://www.usys.ethz.ch/en/studies/environmental-sciences/master/internship.html)

### Course Units for Additional Admission Requirements

The courses below are only available for Master students with additional admission requirements.

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
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</thead>
</table>

Enrollment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

- Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Students understand basic microeconomics and macroeconomics problems and theories. They are able to argue along economic principles and to judge policy measures.

### Literature

Taught competencies

Domain A - Subject-specific Competencies

- Concepts and Theories
- Analytical Competencies
- Decision-making
- Problem-solving

Domain B - Method-specific Competencies

- Analytical Competencies
- Decision-making
- Problem-solving

Domain D - Personal Competencies

- Critical Thinking
- Self-direction and Self-management

406-0062-AAL

**Physics I**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Introduction to the concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective

- Decision-making assessed
- Problem-solving assessed

Content

Book:


Chapters:

1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5)

Literature

see "Content"

406-0063-AAL

**Physics II**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Introduction to the "way of thinking" and the methodology in Physics. The Chapters treated are Magnetism, Refraction and Diffraction of Waves, Elements of Quantum Mechanics with applications to Spectroscopy, Thermodynamics, Phase Transitions, Transport Phenomena.

Objective

- Decision-making assessed
- Problem-solving assessed

Content

Book:


Chapters:


Literature

see "Content"

406-0064-AAL

**Physics I and II**

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract

Concepts and tools in physics: mechanics of point-like and rigid bodies, elasticity theory, elements of hydrostatics and hydrodynamics, periodic motion and mechanical waves.

Objective

- Decision-making assessed
- Problem-solving assessed

Content

Book:


Chapters:

1, 2, 3, 4, 5, 6 (without: 6-5, 6-6, 6-8), 7, 8 (without 8-9), 9, 10 (without 10-10), 11 (without 11-7), 13 (without 13-13, 13-14), 14 (without 14-6), 15 (without 15-3, 15-5), 17 (without 17-5, 17-10), 18 (without 18-5, 18-6, 18-7), 19, 20 (without 20-7, 20-8, 20-9, 20-10, 20-11), 21 (without 21-12), 23, 25 (without 25-9, 25-10), 26 (without 26-4, 26-5, 26-7), 27, 28 (without 28-4, 28-5, 28-8, 28-9, 28-10), 29 (without 29-5, 29-8), 32 (without 32-8), 33 (without 33-4, 33-5, 33-9, 33-10), 34 (without 34-4, 34-6, 34-7), 35 (without 35-2, 35-3, 35-9, 35-11, 35-12, 35-13).
Mathematics I

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
Continuation of the topics of Mathematics I. Main focus: multivariable calculus and partial differential equations.

Content
1. Linear Algebra and Complex Numbers:
   - systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.
2. Single-Variable Calculus:
   - review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.
3. Ordinary Differential Equations:
   - separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

Abstract
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Mathematics II

Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Objective
Main focus of Mathematics II: multivariable calculus and partial differential equations.

Content
1. Multivariable Differential Calculus:
   - functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.
2. Multivariable Integral Calculus:
   - multiple integrals, line and surface integrals, work and flux, Green, Gauss and Stokes theorems, applications.
3. Partial Differential Equations:
   - separation of variables, Fourier series, heat equation, wave equation, Laplace equation, Fourier transform.

Abstract
This course covers mathematical concepts and techniques necessary to model, solve and discuss scientific problems - notably through ordinary differential equations.

Literature
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).
- Thomas, G. B.: Thomas' Calculus, Parts 2 (Pearson Addison-Wesley).

- Verlag Wiley-VCH, 2003, Fr. 77.­
- Band 1: Mechanik und Thermodynamik
- Band 2: Mechanik und Thermodynamik
- Physik für Ingenieure und Naturwissenschaftler
  - Wiley-VCH Verlag, 2002, 544 S, ca.: Fr. 68.-
- Physik für Ingenieure und Naturwissenschaftler
  - Verlag Wiley-VCH, 2003, Fr. 77.-
1. Linear Algebra and Complex Numbers:
- systems of linear equations, Gauss-Jordan elimination, matrices, determinants, eigenvalues and eigenvectors, cartesian and polar forms for complex numbers, complex powers, complex roots, fundamental theorem of algebra.

2. Single-Variable Calculus:
- review of differentiation, linearisation, Taylor polynomials, maxima and minima, antiderivative, fundamental theorem of calculus, integration methods, improper integrals.

3. Ordinary Differential Equations:
- separable ordinary differential equations (ODEs), integration by substitution, 1st and 2nd order linear ODEs, homogeneous systems of linear ODEs with constant coefficients, introduction to 2-dimensional dynamical systems.

4. Multivariable Differential Calculus:
- functions of several variables, partial differentiation, curves and surfaces in space, scalar and vector fields, gradient, curl and divergence.

5. Multivariable Integral Calculus:
- multiple integrals, line and surface integrals, work and flow, Green, Gauss and Stokes theorems, applications.

6. Partial Differential Equations:
- separation of variables, Fourier series, heat equation, wave equation, Laplace equation, Fourier transform.

Literature
- Bretscher, O.: Linear Algebra with Applications (Pearson Prentice Hall).
- Thomas, G. B.: Thomas' Calculus, Parts 2 (Pearson Addison-Wesley).

Prerequisites / notice
- Prerequisites: familiarity with the basic notions from Calculus, in particular those of function and derivative.
- Assistance: Tuesdays and Wednesdays 17-19h, in Room HG E 41.

406-0603-AAL  Stochastics (Probability and Statistics)  E- 4 credits  9R  M. Kalisch
Enrolment ONLY for MSC students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to basic methods and fundamental concepts of statistics and probability theory for non-mathematicians. The concepts are presented on the basis of some descriptive examples. Learning the statistical program R for applying the acquired concepts will be a central theme.

Objective
The objective of this course is to build a solid fundament in probability and statistics. The student should understand some fundamental concepts and be able to apply these concepts to applications in the real world. Furthermore, the student should have a basic knowledge of the statistical programming language "R".

Content
From "Statistics for research" (online)
Ch 1: The Role of Statistics
Ch 2: Populations, Samples, and Probability Distributions
Ch 3: Binomial Distributions
Ch 6: Sampling Distribution of Averages
Ch 7: Normal Distributions
Ch 8: Student's t Distribution
Ch 9: Distributions of Two Variables

From "Introductory Statistics with R (online)"
Ch 1: Basics
Ch 2: The R Environment
Ch 3: Probability and distributions
Ch 4: Descriptive statistics and tables
Ch 5: One- and two-sample tests
Ch 6: Regression and correlation

Literature
- "Statistics for research" by S. Dowdy et. al. (3rd edition); Print ISBN: 9780471267355; Online ISBN: 9780471477433; DOI: 10.1002/0471477435
  From within the ETH, this book is freely available online under: http://onlinelibrary.wiley.com/book/10.1002/0471477435

  From within the ETH, this book is freely available online under: http://www.springerlink.com/content/m17578/

529-2001-AAL  Chemistry I and II  E- 9 credits  19R  J. Cvengros
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
General Chemistry I and II: Chemical bond and molecular structure, chemical thermodynamics, chemical equilibrium, kinetics, acids and bases, electrochemistry

Objective
Introduction to general and inorganic chemistry. Basics of the composition and the change of the material world. Introduction to the thermodynamically controlled physico-chemical processes. Macroscopic phenomena and their explanation through atomic and molecular properties. Using the theories to solve qualitatively and quantitatively chemical and ecologically relevant problems.
Content

1. Stoichiometry
2. Atoms and Elements (Quantenmechanical Model of the Atom)
3. Chemical Bonding
4. Thermodynamics
5. Chemical Kinetics
6. Chemical Equilibrium (Acids and Bases, Solubility Equilibria)
7. Electrochemistry

Lecture notes
Nivaldo J. Tro
Chemistry - A molecular Approach (Pearson), Chapter 1-18

Literature
Housecroft and Constable, CHEMISTRY
Oxtoby, Gillis, Nachtrieb, MODERN CHEMISTRY

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories assessed
Techniques and Technologies assessed

Domain B - Method-specific Competencies
Analytical Competencies assessed
Decision-making assessed
Media and Digital Technologies not assessed
Problem-solving assessed
Project Management not assessed

Domain C - Social Competencies
Communication not assessed
Cooperation and Teamwork not assessed
Customer Orientation not assessed
Leadership and Responsibility not assessed
Self-presentation and Social Influence not assessed
Sensitivity to Diversity not assessed
Negotiation not assessed

Domain D - Personal Competencies
Adaptability and Flexibility not assessed
Creative Thinking assessed
Critical Thinking assessed
Integrity and Work Ethics not assessed
Self-awareness and Self-reflection not assessed
Self-direction and Self-management assessed

529-2002-AAL Chemistry II Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Enrolment is not allowed for Doctoral Students.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Chemistry II: Redox reactions, chemistry of the elements, introduction to organic chemistry

Objective
Erweitern der allgemeinen Grundlagen und Erarbeiten einer Basis, um Prozesse in komplexeren Umweltsystemen (Wasser / Luft / Boden) in ihrem zeitlichen und quantitativen Ablauf verstehen und beurteilen zu können.

Content
1. Redoxreactions

2. Inorganic Chemistry
Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronic structure of the elements.

3. Introduction to organic chemistry
Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups.
Stereochemistry.
Reaction mechanisms: SN1- and SN2-reactions, electrophilic aromatic substitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbyn and carboxyl groups.
Rules for nomenclature of inorganic compounds. Systematic description of the groups of elements in the periodical system and the most important compounds of these elements. Formation of compounds as a consequence of the electronic structure of the elements.

3. Introduction to organic chemistry
Description of the most important classes of compounds and of the functional groups. Principal reactivity of these functional groups.
Stereochemistry.
Reaction mechanisms: SN1- and SN2-reactions, electrophilic aromatic substitutions, eliminations (E1 and E2), addition reactions (C=C and C=O double bonds). Chemistry of carbyn and carboxyl groups.

Lecture notes


### Taught competencies

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<tr>
<th>Domain A - Subject-specific Competencies</th>
<th>Concepts and Theories</th>
<th>assessed</th>
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### 551-0001-AAL General Biology I

**E-** 3 credits 6R  U. Sauer, O. Y. Martin, A. Widmer

**Abstract**

Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

**Objective**

The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

**Content**

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogenetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

**Lecture notes**

No script

**Literature**


**Prerequisites / notice**

This is a virtual self-study lecture for non-german speakers of the "Allgemeine Biology I (551-0001-00L) lecture. The exam will be written jointly with the participants of this lecture.

Example exam questions will be discussed during the lectures, and old exam questions are kept by the various student organisations. If necessary, please contact Prof. Uwe Sauer (sauer@ethz.ch) for details regarding the exam.

### 551-0003-AAL General Biology II

**E-** 7 credits 13R  U. Sauer, K. Bomblies, O. Y. Martin, A. Widmer

**Abstract**

General Biology I: Organismic biology to teach the basic principles of classical and molecular genetics, evolutionary biology and phylogeny.

General Biology II: Molecular biology approach to teach the basic principles of biochemistry, cell biology, cugenetics, evolutionary biology and form and function of vacular plants.

**Objective**

General Biology I: The understanding of basic principles of biology (inheritance, evolution and phylogeny) and an overview of the diversity of life.

General Biology II: The understanding basic concepts of biology; the hierarchy of the structural levels of biological organisation, with particular emphasis on the cell and its molecular functions, the fundamentals of metabolism and molecular genetics, as well as form and function of vacular plants.
General Biology I: General Biology I focuses on the organismal biology aspects of genetics, evolution and diversity of life in the Campbell chapters 12-34.

Week 1-7 by Alex Widmer, Chapters 12-25
12 Cell biology Mitosis
13 Genetics Sexual life cycles and meiosis
14 Genetics Mendelian genetics
15 Genetics Linkage and chromosomes
20 Genetics Evolution of genomes
21 Evolution How evolution works
22 Evolution Phylogetic reconstructions
23 Evolution Microevolution
24 Evolution Species and speciation
25 Evolution Macroevolution

Week 8-14 by Oliver Martin, Chapters 26-34
26 Diversity of Life Introduction to viruses
27 Diversity of Life Prokaryotes
28 Diversity of Life Origin & evolution of eukaryotes
29 Diversity of Life Nonvascular&seedless vascular plants
30 Diversity of Life Seed plants
31 Diversity of Life Introduction to fungi
32 Diversity of Life Overview of animal diversity
33 Diversity of Life Introduction to invertebrates
34 Diversity of Life Origin & evolution of vertebrates

General Biology II: The structure and function of biomacromolecules; basics of metabolism; tour of the cell; membrane structure and function; basic energetics of cellular processes; respiration, photosynthesis; cell cycle, from gene to protein; structure and growth of vascular plants, resource acquisition and transport, soil and plant nutrition.

Specifically the following Campbell chapters will be covered:
3 Biochemistry Chemistry of water
4 Biochemistry Carbon: the basis of molecular diversity
5 Biochemistry Biological macromolecules and lipids
7 Cell biology Cell structure and function
8 Cell biology Cell membranes
10 Cell biology Respiration: introduction to metabolism
10 Cell biology Cell respiration
11 Cell biology Photosynthetic processes
16 Genetics Nucleic acids and inheritance
17 Genetics Expression of genes
18 Genetics Control of gene expression
19 Genetics DNA Technology
35 Plant structure&function Plant Structure and Growth
36 Plant structure&function Transport in vascular plants
37 Plant structure&function Plants signal and behavior
38 Plant structure&function Reproduction of flowering plants
39 Plant structure&function Plants signal and behavior

Lecture notes No script
Prerequisites / notice Basic general and organic chemistry

This is a virtual self-study lecture for non-German speakers of the "Allgemeine Biology I (551-0001-00L) and "Allgemeine Biology II (551-0002-00L) lectures. The exam will be written jointly with the participants of this lecture.

701-0023-AAL Atmosphere E- 3 credits 6R E. Fischer, T. Peter
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Objective Understanding of basic physical and chemical processes in the atmosphere. Understanding of mechanisms of and interactions between: weather - climate, atmosphere - ocean - continents, troposphere - stratosphere. Understanding of environmentally relevant structures and processes on vastly differing scales. Basis for the modelling of complex interrelations in the atmosphere.

Content Basic principles of the atmosphere, physical structure and chemical composition, trace gases, atmospheric cycles, circulation, stability, radiation, condensation, clouds, oxidation capacity and ozone layer.

Lecture notes Written information will be supplied.


701-0071-AAL Mathematics III: Systems Analysis E- 4 credits 9R R. Knutti, H. Wernli
Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.
Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract The objective of the systems analysis course is to deepen and illustrate the mathematical concepts on the basis of a series of very concrete examples. Topics covered include: linear box models with one or several variables, non-linear box models with one or several variables, time-discrete models, and continuous models in time and space.

Objective Learning and applying of concepts (models) and quantitative methods to address concrete problems of environmental relevance. Understanding and applying the systems-analytic approach, i.e., Recognizing the core of the problem - simplification - quantitative approach - prediction.

### Content
- Introduction to principles of models: one-dimensional linear box models; multi-dimensional linear box models; nonlinear box models; models in space and time

### Lecture notes
- Teaching material: book (see literature).

### Literature
  

### 701-0106-AAL
**Mathematics V: Applied Deepening of Mathematics I - III**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

#### Abstract
Selected mathematical topics are presented for later use in more specialised lectures. Part of the topics were already discussed in the lectures Mathematics I-III. Here, they should be shortly recapitulated and most importantly applied to practical problems. If necessary, new mathematical concepts and methods will be introduced in order to solve challenging and inspiring problems from practice.

#### Objective
The aim of this lecture is to prepare the students for the more specialised lectures. They should become more familiar with the mathematical background, the mathematical concepts and most of all with their application and interpretation.

#### Content
- Practical examples from the following areas will be discussed: ordinary differential equations; eigenvalue problems from linear algebra; systems of linear and nonlinear differential equations; partial differential equations (diffusion, transport, waves).

### 701-0243-AAL
**Biology III: Essentials of Ecology**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

#### Abstract
Original language Students will understand how ecological processes operate in natural communities. They will appreciate how mathematical theory, field experimentation, and observational studies combine to generate a predictive science of ecological processes.

#### Objective
Upon completing the course, students will be able to:

- Understand the factors determining the outcome of species interactions in communities, and how this information informs management.
- Apply theoretical knowledge on species interactions to predict the potential outcomes of novel species introductions.
- Understand the role of spatial structure in mediating population dynamics and persistence, species interactions, and patterns of species diversity.
- Use population and community models to predict the stability of interactions between predators and prey and between different competitors.
- Understand the conceptual basis of predictions concerning how ecological communities will respond to climate change.

#### Content
- Readings from a text book will focus on understanding central processes in community ecology. Topics will include demographic and spatial structure, consumer resource interactions, food webs, competition, invasion, and the maintenance of species diversity. Each of these more conceptual topics will be discussed in concert with their applications to the conservation and management of species and communities in a changing world.

### 701-0401-AAL
**Hydrosphere**

**Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.**

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

#### Abstract
The course aims to describe the relevant processes that control the terrestrial water cycle. Energy and mass exchange, mixing and transport processes are described and the coupling of the hydrosphere with the atmosphere and the solid Earth are discussed.

#### Objective
- Qualitative and quantitative understanding on how physical (and geochemical) processes control the natural dynamics in groundwater, lakes ans oceans and constrain the exchange of mass and energy.
- Understo the role of spatial structure in mediating population dynamics and persistence, species interactions, and patterns of species diversity.
- Understand the factors determining the outcome of species interactions in communities, and how this information informs management.

#### Content
- Topics of the course.
  - Physical properties of water (i.e. density and equation of state).
  - global water resources
- Exchange at boundaries
  - energy (thermal & kinetic), gas exchange
- Mixing and transport processes in open waters
  - vertical stratification, large scale transport
  - turbulence and mixing
- mixing and exchange processes in rivers
  - Groundwater and its dynamics
  - ground water as part of the terrestrial water cycle
  - ground water hydraulics, Darcy's law
  - aquifers and their properties
  - hydrochemistry and tracer
  - ground water use
- Case studies
  - 1. Water as resource, 2. Water and climate

#### Lecture notes
In addition to the self-learning literature handouts are distributed.
This course covers the basics of atmospheric physics, which consist of:
- cloud and precipitation formation
- thermodynamics
- aerosol physics
- cloud formation
- precipitation processes, storms
- importance of aerosols and clouds for climate and artificial weather modification

Ground water:
  - Chapters 1 - 6, 8, 10, 11.

Optional additional readers:

701-0473-AAL Weather Systems

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
The students learn about the dynamical features of the Earth's atmosphere. They interpret satellite imagery and learn about basic concepts in dynamical meteorology. The global circulation is briefly discussed, before introducing the Eulerian and the Lagrangian perspective, which are used to study air streams in extratropical cyclones and to investigate basic aspects in mountain meteorology.

Objective
The students are able to:
- explain basic measurement and analysis techniques that are relevant in atmospheric dynamics
- to discuss the mathematical basics of atmospheric dynamics, based on selected atmospheric flow phenomena
- to explain the basic dynamics of the global circulation and of synoptic- and meso-scale flow features
- to explain how mountains influence the atmospheric flow on different scales
- basic understanding of the role of moist adiabatic processes for weather systems and why stable water isotopes are useful in this context

Content
Satellite observations; analysis of vertical soundings; geostrophic and thermal wind; cyclones at mid-latitude; global circulation; north-atlantic oscillation; atmospheric blocking situations; Eulerian and Lagrangian perspective; potential vorticity; Alpine dynamics (storms, orographic wind); planetary boundary layer

Lecture notes
Lecture notes and slides

Literature
Atmospheric Science, An Introductory Survey
- John M. Wallace and Peter V. Hobbs, Academic Press

701-0475-AAL Atmospheric Physics

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This course covers the basics of atmospheric physics, which consist of: cloud and precipitation formation, thermodynamics, aerosol physics, radiation as well as the impact of aerosols and clouds on climate and artificial weather modification.

Objective
Students are able to:
- to explain the mechanisms of cloud and precipitation formation using knowledge of humidity processes and thermodynamics
- to explain how aerosols influence climate and air quality
- to evaluate the significance of clouds and aerosol particles for climate and artificial weather modification

Content
- Moist processes/thermodynamics; aerosol physics; cloud formation; precipitation processes, storms; importance of aerosols and clouds for climate and weather modification, clouds and precipitation

Lecture notes
Powerpoint slides and script will be made available

Literature

701-0501-AAL Pedosphere

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
Introduction to the formation and properties of soils as a function of parent rock, landscape position, climate, and soil organisms. Complex relationships between soil forming processes, physical and chemical soil properties, soil biota, and ecological soil properties.

Objective
Understanding of soils as integral parts of ecosystems, development and distribution of soils as a function of environmental factors, and processes leading to soil degradation.

Content
Definition of the pedosphere, soil functions, rocks as parent materials, minerals and weathering, soil organisms, soil organic matter, physical soil properties and functions, chemical soil properties and functions, soil formation, principles of soil classification, global soil regions, soil fertility, land use and soil degradation.

Literature

Prerequisites / notice
Prerequisites: Basic knowledge in chemistry, biology and geology.

701-0721-AAL Psychology

- Enrolment ONLY for MSc students with a decree declaring this course unit as an additional admission requirement.

Any other students (e.g. incoming exchange students, doctoral students) CANNOT enrol for this course unit.

Abstract
This is an introductory course in psychology. This course will emphasize cognitive psychology and the psychological experiment.
Objective

Knowledge of key concepts and exemplary theories of psychology and their relation to “daily” psychology. Comprehension of relation between theory and experiment in psychology.

Goals: Learning how psychologists are thinking, a side change from the ETH natural science perspective to psychological thinking.

Domains of psychology:
- Psychology fields
- Concept definitions of psychology
- Theories of psychology
- Methods of psychology
- Results of psychology

Capability:
Be able to define a psychological research question
Basics understanding of role of psychology

Comprehension:
Psychology as a science of experience and behavior of the human

Content

Einführung in die psychologische Forschung und Modellbildung unter besonderer Berücksichtigung der kognitiven Psychologie und des psychologischen Experiments. Themen sind u.a.: Wahrnehmung; Lernen und Entwicklung; Denken und Problemlösen; Kognitive Sozialpsychologie; Risiko und Entscheidung.

Literature

English book of Zimbardo (http://www.amazon.de/Psychology-Life-Discovering-Psych-Lab/dp/0205654770/ref=sr_1_2?s=books-intl-de&ie=UTF8&qid=1317208260&sr=1-2)


Prerequisites / notice

Determine with Prof. Dr. Michael Siegrist the chapters in “Zimbardo” which are compulsory reading

Read the two Psychology chapters (6 + 7) from the book of Prof. Roland W. Scholz
Hydrodynamics and Cavitation

1. Identify and describe dominant effects in liquid fluid flows through physical modelling.
2. Identify hydrodynamic instabilities and discuss the stability region.
3. Describe fragmentation of liquids.
4. Explain tension, nucleation and phase-change in liquids.
5. Describe hydrodynamic cavitation and its consequences in physical terms.
6. Recognise experimental techniques and industrial and medical applications for cavitation.

Prerequisites / notice
Students should be familiar with a compiled programming language (C, C++ or Fortran). Exercises and exams will be designed using C++. The course will not teach basics of programming. Some familiarity using the command line is assumed. Students should also have a basic understanding of diffusion and advection processes, as well as their underlying partial differential equations.

Lecture notes
Class notes, handouts

Literature
- Class notes, handouts

Hydrodynamics and Cavitation

1. Describe fragmentation of liquids.
2. Describe hydrodynamic cavitation and its consequences in physical terms.
3. Recognise experimental techniques and industrial and medical applications for cavitation.

Prerequisites / notice
Fluid dynamics I & II or equivalent


Lecture notes
Lecture Notes containing copies of the presented slides.

Literature
- Lecture Notes containing copies of the presented slides.

Radiation Heat Transfer


Prerequisites / notice
Lecture Notes containing copies of the presented slides.

Literature
- Lecture Notes containing copies of the presented slides.

Renewable Energy Technologies

1. Renewable energy technologies: solar PV, solar thermal, biomass, wind, geothermal, hydro, waste-to-energy. Focus is on the engineering aspects.
2. Students learn the potential and limitations of renewable energy technologies and their contribution towards sustainable energy utilization.

Prerequisites / notice
Lecture Notes containing copies of the presented slides.

Literature
- Lecture Notes containing copies of the presented slides.

Thermodynamics I, II, and III of D-MAVT.
Fluid Dynamics with the Lattice Boltzmann Method

Abstract

Methods like molecular dynamics, DSMC, lattice Boltzmann etc are being increasingly used by engineers all over and these methods require knowledge of kinetic theory and statistical mechanics which are traditionally not taught at engineering departments. The goal of this course is to give an introduction to ideas of kinetic theory and non-equilibrium thermodynamics with a focus on developing simulation algorithms and their realizations.

During the course, students will be able to develop a lattice Boltzmann code on their own. Practical issues about implementation and performance on parallel machines will be demonstrated hands on.

Central element of the course is the completion of a lattice Boltzmann code (using the framework specifically designed for this course).

The course will also include a review of topics of current interest in various fields of fluid dynamics, such as multiphase flows, reactive flows, microflows among others.

Optionally, we offer an opportunity to complete a project of student's choice as an alternative to the oral exam. Samples of projects completed by previous students will be made available.

The course builds upon three parts:

I. Elementary kinetic theory and lattice Boltzmann simulations introduced on simple examples.
II. Theoretical basis of statistical mechanics and kinetic equations.
III. Lattice Boltzmann method for real-world applications.

The content of the course includes:

1. Background: Elements of statistical mechanics and kinetic theory:
   - Particle's distribution function, Liouville equation, entropy, ensembles; Kinetic theory: Boltzmann equation for rarefied gas, H-theorem, hydrodynamic limit and derivation of Navier-Stokes equations, Chapman-Enskog method, Grad method, boundary conditions; mean-field interactions, Vlasov equation;
   - Kinetic models: BGK model, generalized BGK model for mixtures, chemical reactions and other fluids.

2. Basics of the Lattice Boltzmann Method and Simulations:
   - Minimal kinetic models: lattice Boltzmann method for single-component fluid, discretization of velocity space, time-space discretization, boundary conditions, forcing, thermal models, mixtures.

3. Hands on:
   - Development of the basic lattice Boltzmann code and its validation on standard benchmarks (Taylor-Green vortex, lid-driven cavity flow etc).

4. Practical issues of LBM for fluid dynamics simulations:
   - Lattice Boltzmann simulations of turbulent flows; numerical stability and accuracy.

5. Microflow:
   - Rarefaction effects in moderately dilute gases; Boundary conditions, exact solutions to Couette and Poiseuille flows; micro-channel simulations.

6. Advanced lattice Boltzmann methods:
   - Entropic lattice Boltzmann scheme, subgrid simulations at high Reynolds numbers; Boundary conditions for complex geometries.

7. Introduction to LB models beyond hydrodynamics:
   - Relativistic fluid dynamics; flows with phase transitions.

Lecture notes

Lecture notes on the theoretical parts of the course will be made available.
Selected original and review papers are provided for some of the lectures on advanced topics.
Handouts and basic code framework for implementation of the lattice Boltzmann models will be provided.

Prerequisites / notice

The course addresses mainly graduate students (MSc/Ph D) but BSc students can also attend.

Microscale Acoustofluidics

Abstract

In this lecture the basics as well as practical aspects (from modelling to design and fabrication) are described from a solid and fluid mechanics perspective with applications to microsystems and lab on a chip devices.

Objective

Understanding acoustophoresis, the design of devices and potential applications.

Microscale Acoustofluidics

Abstract

The course provides an introduction to theoretical foundations and practical usage of the Lattice Boltzmann Method for fluid dynamics simulations.

Objective

The students should become familiar with the fundamentals and with application examples of chemically reactive processes in energy conversion (combustion engines in particular) as well as the synthesis of new materials.

Content


Literature

Critical Thinking

After completing the course, you will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

Prerequisites / notice

Solid and fluid continuum mechanics. Notice: The exercise part is a mixture of presentation, lab sessions (both compulsory) and hand in homework.

Taught competencies

Domain A - Subject-specific Competencies
Concepts and Theories
Techniques and Technologies

Domain B - Method-specific Competencies
Analytical Competencies
Decision-making
Media and Digital Technologies
Problem-solving
Project Management

Domain C - Social Competencies
Communication
Cooperation and Teamwork
Customer Orientation
Leadership and Responsibility
Self-presentation and Social Influence
Sensitivity to Diversity
Negotiation

Domain D - Personal Competencies
Critical Thinking
Integrity and Work Ethics
Self-direction and Self-management

151-0902-00L Micro- and Nanoparticle Technology

Number of participants is limited to 20.
Additional ones could be enrolled by permission of the lecturer.

Abstract
Particles are everywhere and nano is the new scale in science & engineering as micro was ~200 years ago. For highly motivated students, this exceptionally demanding class gives a flavor of nanotechnology with hands-on student projects on gas-phase particle synthesis & applications capitalizing on particle dynamics (diffusion, coagulation etc.), shape, size distribution and characterization.

Objective
This course aims to familiarize motivated M/BSc students with some of the basic phenomena of particles at the nanoscale, thereby illustrating the links between physics, chemistry, materials science through hands-on experience. Furthermore it aims to give an overview of the field with motivating lectures from industry and academia, including the development of technologies and processes based on particle technology with introduction to design methods of mechanical processes, scale-up laws and optimal use of materials and energy. Most importantly, this course aims to develop the creativity and sharpen the communication skills of motivated students through their individual projects, a PERFECT preparation for the M/BSc thesis (e.g. efficient & critical literature search, effective oral/written project presentations), the future profession itself and even life, in general, are always there.

Content
The course objectives are best met primarily through the individual student projects which may involve experiments, simulations or critical & quantitative reviews of the literature. Projects are conducted individually under the close supervision of MSc, PhD or post-doctoral students. Therein, a 2-page proposal is submitted within the first two semester weeks addressing explicitly, at least, 10 well-selected research articles and thoughtful meetings with the project supervisor. The proposal address 3 basic questions: a) how important is the project; b) what has been done already in that field and c) what will be done by the student. Detailed feedback on each proposal is given by the supervisor, assistant and professor two weeks later. Towards the end of the semester, a 10-minute oral presentation is given by the student followed by 10 minutes Q&A. A 10-page final report is submitted by noon of the last day of the semester. The project supervisor will provide guidance throughout the course. Lectures include some of the following:
- Overview & Project Presentation
- Particle Size Distribution
- Particle Diffusion
- Coagulation
- Agglomeration & Coalescence
- Particle Growth by Condensation
- Control of particle size & structure during gas-phase synthesis
- Multi-scale design of aerosol synthesis of particles
- Particle Characterization
- Aerosol manufacture of nanoparticles
- Forces acting on Single Particles in a Flow Field
- Fixed and Fluidized Beds
- Separations of Solid-Liquid & Solid-Gas systems
- Emulsions/droplet formation/microfluidics
- Gas Sensors
- Coaching for proposal & report writing as well as oral presentations

Literature
Prerequisites / notice

FluidMechanik I, Thermodynamik I&II & "clean" 5th semester BSc student standing in D-MAVT (no block 1 or 2 obligations). Students attending this course are expected to allocate sufficient additional time within their weekly schedule to successfully conduct their project. As exceptional effort will be required! Having seen "Chasing Mavericks" (2012) by Apted & Henson, "Unbroken" (2014) by Angelina Jolie and, in particular, "The Salt of the Earth" (2014) by Win Wenders might be helpful and even motivating. These movies show how methodic effort can bring superior and truly unexpected results (e.g. stay under water for 5 minutes to overcome the fear of riding huge waves or merciless Olympic athlete training that help survive 45 days at a raft in Pacific Ocean followed by 2 years in a Japanese POW camp during WWII).

151-0905-00L Medical Technology Innovation - From Concept to Clinics

Abstract
Project-oriented learning on how to develop technological solutions to address unmet clinical needs.

Objective
After completing the course, students will be able to effectively collaborate with medical doctors in order to identify important unmet clinical needs. You will be able to ideate and develop appropriate engineering solutions and implementation strategies for real-world clinical problems. This lecture aims to prepare you for typical engineering challenges in the real-world where - in addition to the development of an elegant solution - interdisciplinary team work and effective communication play a key role.

Literature will be available on the moodle.

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories
- Techniques and Technologies

Domain B - Method-specific Competencies
- Analytical Competencies
- Decision-making
- Problem-solving
- Project Management

Domain C - Social Competencies
- Communication
- Cooperation and Teamwork
- Customer Orientation
- Leadership and Responsibility
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

Domain D - Personal Competencies
- Adaptability and Flexibility
- Creative Thinking
- Critical Thinking
- Integrity and Work Ethics
- Self-awareness and Self-reflection
- Self-presentation and Social Influence
- Sensitivity to Diversity
- Negotiation

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**151-0911-00L Introduction to Plasmonics**  
W 4 credits 2V+1U  D. J. Norris  
*Does not take place this semester.*

**Abstract**
This course provides fundamental knowledge of surface plasmon polaritons and discusses their applications in plasmonics.

**Objective**
Electromagnetic oscillations known as surface plasmon polaritons have many unique properties that are useful across a broad set of applications in biology, chemistry, physics, and optics. The field of plasmonics has arisen to understand the behavior of surface plasmon polaritons and to develop applications in areas such as catalysis, imaging, photovoltaics, and sensing. In particular, metallic nanoparticles and patterned metallic interfaces have been developed to utilize plasmonic resonances. The aim of this course is to provide the basic knowledge to understand and apply the principles of plasmonics. The course will strive to be approachable to students from a diverse set of science and engineering backgrounds.

**Content**
- Fundamentals of Plasmonics
  - Basic electromagnetic theory
  - Optical properties of metals
  - Surface plasmon polaritons on surfaces
  - Surface plasmon polariton propagation
  - Localized surface plasmons

- Applications of Plasmonics
  - Waveguides
  - Extraordinary optical transmission
  - Enhanced spectroscopy
  - Sensing
  - Metamaterials

**Lecture notes**
Class notes and handouts

**Literature**

**Prerequisites / notice**
Physics I, Physics II

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**151-0913-00L Introduction to Photonics**  
W 4 credits 2V+2U  R. Quidant, J. Ortega Arroyo

**Abstract**
This course introduces students to the main concepts of optics and photonics. Specifically, we will describe the laws obeyed by optical waves and discuss how to use them to manipulate light.

**Objective**
Photonics, the science of light, has become ubiquitous in our lives. Control and manipulation of light is what enables us to interact with the screen of our smart devices and exchange large amounts of complex information. Photonics has also taken a preponderant role in cutting-edge science, allowing for instance to image nanospecimens, detect diseases or sense very tiny forces. The purpose of this course is three-fold: (i) We first aim to provide the fundamentals of photonics, establishing a solid basis for more specialised courses. (ii) Beyond theoretical concepts, our intention is to have students develop an intuition on how to manipulate light in practise. (iii) Finally, the course highlights how the taught concepts apply to modern research as well as to everyday life technologies (LCD screens, polarisation sun glasses, anti-reflection coating etc...). Content, including videos of laboratory experiments, has been designed to be approachable by students from a diverse set of science and engineering backgrounds.
## Content

### I- BASICS OF WAVE THEORY
1) General concepts
2) Differential wave equation
3) Wavefront
4) Plane waves and Fourier decomposition of optical fields
5) Spherical waves and Huygens-Fresnel principle

### II- ELECTROMAGNETIC WAVES
1) Maxwell equations
2) Wave equation for EM waves
3) Dielectric permittivity
4) Refractive index
5) Nonlinear optics
6) Polarisation and polarisation control

### III- PROPAGATION OF LIGHT
1) Waves at an interface
2) The Fresnel equations
3) Total internal reflection
4) Evanescent waves
5) Dispersion diagram

### IV- INTERFERENCES
1) General considerations
2) Temporal and spatial coherence
3) The Young double slit experiment
4) Diffraction gratings
5) The Michelson interferometer
6) Multi-wave interference
7) Antireflecting coating and interference filters
8) Optical holography

### V- LIGHT MANIPULATION
1) Optical waveguides
2) Photonic crystals
3) Metamaterials and metasurfaces
4) Optical cavities

### VI- INTRODUCTION TO OPTICAL MICROSCOPY
1) Basic concepts
2) Direct and Fourier imaging
3) Image formation
4) Fluorescence microscopy
5) Scattering-based microscopy
6) Digital holography
7) Computational imaging

### VII- OPTICAL FORCES AND OPTICAL TWEEZERS
1) History of optical forces
2) Theory of optical trapping
3) Atom cooling
4) Optomechanics
5) Plasmonic trapping
6) Applications of optical tweezers

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**151-0917-00L  Mass Transfer**

<table>
<thead>
<tr>
<th>Mass Transfer</th>
<th>W</th>
<th>4 credits</th>
<th>2V+2U</th>
<th>S. E. Pratsinis, V. Mavrantzas, C.-J. Shih</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>This course presents the fundamentals of transport phenomena with emphasis on mass transfer. The physical significance of basic principles is elucidated and quantitatively described. Furthermore the application of these principles to important engineering problems is demonstrated.</td>
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<td></td>
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</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>Fick's laws; application and significance of mass transfer; comparison of Fick's laws with Newton's and Fourier's laws; derivation of Fick's 2nd law; diffusion in dilute and concentrated solutions; rotating disk; dispersion; diffusion coefficients, viscosity and heat conduction (Pr and Sc numbers); Brownian motion; Stokes-Einstein equation; mass transfer coefficients (Nu and Sh numbers); mass transfer across interfaces; Analogies for mass-, heat-, and momentum transfer in turbulent flows; film-, penetration-, and surface renewal theories; simultaneous mass, heat and momentum transfer (boundary layers); homogeneous and heterogeneous reversible and irreversible reactions; diffusion-controlled reactions; mass transfer and first order heterogeneous reaction. Applications.</td>
</tr>
<tr>
<td>Prerequisites / notice</td>
<td></td>
<td></td>
<td></td>
<td>Students attending this highly-demanding course are expected to allocate sufficient time within their weekly schedule to successfully conduct the exercises.</td>
</tr>
</tbody>
</table>

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**151-0927-00L  Rate-Controlled Separations in Fine Chemistry**

<table>
<thead>
<tr>
<th>Rate-Controlled Separations in Fine Chemistry</th>
<th>W</th>
<th>6 credits</th>
<th>3V+1U</th>
<th>M. Mazzotti, V. Becattini</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td></td>
<td></td>
<td></td>
<td>The students are supposed to obtain detailed insight into the fundamentals of separation processes that are frequently applied in modern life science processes in particular, fine chemistry and biotechnology.</td>
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<td></td>
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<tr>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td>The class covers separation techniques that are central in the purification and downstream processing of chemicals and biopharmaceuticals. Examples from both areas illustrate the utility of the methods: 1) Adsorption and chromatography; 2) Membrane processes; 3) Crystallization and precipitation.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td></td>
<td></td>
<td></td>
<td>Handouts during the class</td>
</tr>
</tbody>
</table>

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Literature
Recommendations for text books will be covered in the class

Prerequisites / notice
Requirements (recommended, not mandatory): Thermal separation Processes I (151-0926-00) and Modelling and mathematical methods in process and chemical engineering (151-0940-00)

Taught competencies

Domain A - Subject-specific Competencies
- Concepts and Theories: assessed
- Techniques and Technologies: assessed

Domain B - Method-specific Competencies
- Analytical Competencies: not assessed
- Decision-making: assessed
- Media and Digital Technologies: not assessed
- Problem-solving: assessed
- Project Management: not assessed
- Leadership and Responsibility: not assessed
- Self-presentation and Social Influence: not assessed
- Sensitivity to Diversity: not assessed
- Negotiation: assessed

Domain C - Social Competencies
- Communication: assessed
- Cooperation and Teamwork: not assessed
- Customer Orientation: not assessed
- Self-presentation and Self-reflection: not assessed
- Sensitivity to Diversity: not assessed

Domain D - Personal Competencies
- Adaptable and Flexibility: not assessed
- Critical Thinking: assessed
- Integrity and Work Ethics: not assessed
- Self-direction and Self-management: not assessed

151-0951-00L
Process Design and Safety
W 4 credits 2V+1U
F. Trachsel, C. Hutter

Abstract
The lecture Process Design and Safety deals with the fundamentals of project management, scale-up, dimensioning and safety of chemical process equipment and plants.

Objective
The objective of the lecture is to expound the engineering design approach of important elements in chemical plant design.

Content
Fundamentals in Chemical engineering Design;
Project Management,
Cost estimate,
Materials and Corrosion,
Piping and Armatures,
Pumps,
Reactors and Scale-up,
Safety of chemical processes,
Patents

Lecture notes
The lecture slides will be distributed.

Literature

Prerequisites / notice
A 1-day excursion including a visit of a chemical plant will be part of the lecture.

151-0957-00L
Practica in Process Engineering I
W 2 credits 2P
S. A. Meyer, M. Tibbitt

Prerequisites: "Einführung in Verfahrenstechnik" (151-0973-00L) and further process engineering courses.

Abstract
Practical training at pilot facilities for fundamental processing steps, typical laboratory and pilot facility experiments.

Objective
Getting acquainted with unit operations, measuring tools and data processing

Content
4 modules in total (3 from Prof. Norris, 1 from Prof. Mark Tibbitt)
Details will be communicated at the beginning of the semester.

Residence time distribution
Tibbitt

Peroxevskite Nanocrystals: Synthesis and Characterization
Norris

Thin Film Deposition - Sputtering
Norris

Scanning Electron Microscope Imaging
Norris

Lecture notes
Descriptions of the practica available

Literature
Information in the description

529-0613-01L
Process Simulation and Flowsheeting
W 6 credits 3G
G. Guillén Gosálbez

Abstract
This course encompasses the theoretical principles of chemical process simulation and optimization, as well as its practical application in process analysis. The techniques for simulating stationary and dynamic processes are presented, and illustrated with case studies. Commercial software packages (Aspen) are introduced for solving process flowsheeting and optimization problems.

Objective
This course aims to develop the competency of chemical engineers in process flowsheeting, process simulation and process optimization. Specifically, students will develop the following skills:
- Deep understanding of chemical engineering fundamentals: the acquisition of new concepts and the application of previous knowledge in the area of chemical process systems and their mechanisms are crucial to intelligently simulate and evaluate processes.
- Modeling of general chemical processes and systems: students should be able to identify the boundaries of the system to be studied and develop the set of relevant mathematical relations, which describe the process behavior.
- Mathematical reasoning and computational skills: the familiarization with mathematical algorithms and computational tools is essential to be capable of achieving rapid and reliable solutions to simulation and optimization problems. Hence, students will learn the mathematical principles necessary for process simulation and optimization, as well as the structure and application of process simulation software. Thus, they will be able to develop criteria to correctly use commercial software packages and critically evaluate their results.
- Process optimization: the students will learn how to formulate optimization problems in mathematical terms, the main type of optimization problems that exist (i.e., LP, NLP, MILP and MINLP) and the fundamentals of the optimization algorithms implemented in commercial solvers.
Overview of process simulation and flowsheeting:
- Definition and fundamentals
- Fields of application
- Case studies

Process simulation:
- Modeling strategies of process systems
- Mass and energy balances and degrees of freedom of process units and process systems

Process flowsheeting:
- Flowsheet partitioning and tearing
- Solution methods for process flowsheeting
- Simultaneous methods
- Sequential methods

Process optimization and analysis:
- Classification of optimization problems
- Linear programming, LP
- Non-linear programming, NLP
- Mixed-integer linear programming, MILP
- Mixed-integer nonlinear programming, MINLP

Commercial software for simulation (Aspen Plus):
- Thermodynamic property methods
- Reaction and reactors
- Separation / columns
- Convergence, optimization & debugging

Literature
An exemplary literature list is provided below:
- Smith, R. Chemical process design and integration, Wiley (2005).

Prerequisites / notice
A basic understanding of material and energy balances, thermodynamic property methods and typical unit operations (e.g., reactors, flash separations, distillation/absorption columns etc.) is required.

Multidisciplinary Courses
The students are free to choose individually from the Course Catalogue of ETH Zurich, ETH Lausanne and the Universities of Zurich (https://www.uzh.ch/cmsssl/en/studies/application/chmobilityin.html) and St. Gallen.

Course Catalogue of ETH Zurich

Semester Project

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1008-00L</td>
<td>Semester Project Process Engineering Only for Process Engineering MSc.</td>
<td>O</td>
<td>8 credits</td>
<td>17A</td>
<td>Professors</td>
</tr>
</tbody>
</table>

Abstract
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program. Tutors propose the subject of the project, elaborate the project plan, and define the roadmap together with their students, as well as monitor the overall execution.

Objective
The semester project is designed to train the students in the solution of specific engineering problems. This makes use of the technical and social skills acquired during the master's program.

Industrial Internship

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Type</th>
<th>ECTS</th>
<th>Hours</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>151-1090-00L</td>
<td>Industrial Internship Access to the company list and request for recognition under <a href="http://www.mavt.ethz.ch/praxis">www.mavt.ethz.ch/praxis</a>.</td>
<td>O</td>
<td>8 credits</td>
<td></td>
<td>external organisers</td>
</tr>
</tbody>
</table>

Abstract
No registration required via myStudies.

Objective
The main objective of the minimum twelve-week internship is to expose Master’s students to the industrial work environment. The aim of the Industrial Internship is to apply engineering knowledge to practical situations.

GESS Science in Perspective

- see GESS Science in Perspective: Language Courses ETH/UZH
- see GESS Science in Perspective: Type A: Enhancement of Reflection Capability

Recommended GESS Science in Perspective (Type B) for D-MAVT.

Master’s Thesis
Students who fulfill the following criteria are allowed to begin with their Master's Thesis:

a. successful completion of the bachelor program;

b. fulfilling of any additional requirements necessary to gain admission to the master programme;

c. successful completion of the semester project and industrial internship;

d. achievement of 28 ECTS in the category "Core Courses".

The Master's Thesis must be approved in advance by the tutor and is supervised by a professor of ETH Zurich.

Abstract

Master's programs are concluded by the master's thesis. The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem. The subject of the master's thesis, as well as the project plan and roadmap, are proposed by the tutor and further elaborated with the student.

Objective

The thesis is aimed at enhancing the student's capability to work independently toward the solution of a theoretical or applied problem.

Seminar on Particle Technology

The goal of the lecture is to convey a basic knowledge in the area of FV materials as well as their construction and production processes and to empower the students to apply the knowledge gained to address current problems in research and practice.

Students attend and give research presentations for the research they plan to do and at the end of the semester they defend their results and answer questions from research scientists. Familiarize the students with the latest in this field.

Research Topics in Biomedical Engineering

Does not take place this semester.

Current topics in Biomedical Engineering presented by speakers from academia and industry.

Getting insight into actual areas and problems of Biomedical Engineering an Health Care.

Process Engineering Master - Key for Type

O  Compulsory

W+  Eligible for credits and recommended

W  Eligible for credits

Z  Courses outside the curriculum

Dr  Suitable for doctorate

Key for Hours

V  lecture

G  lecture with exercise

U  exercise

S  seminar

K  colloquium

P  practical/laboratory course

A  independent project

D  diploma thesis

R  revision course / private study

ECTS  European Credit Transfer and Accumulation System

Special students and auditors need special permission from the lecturers.